ND-J360-GB (SR)

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 828 202 A2

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
11.03.1998 Bulletin 1998/11

(51) Int. Cl.6: G03H 1/04

(21) Application number: 97115344.0

(22) Date of filing: 04.09.1997

(84) Designated Contracting States:
AT BE CH DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE

(30) Priority: 05.09.1996 JP 257588/96
02.09.1997 JP 254346/97

(71) Applicant: DENSO CORPORATION
Kariya-City Aichi-Pref. 448 (JP)

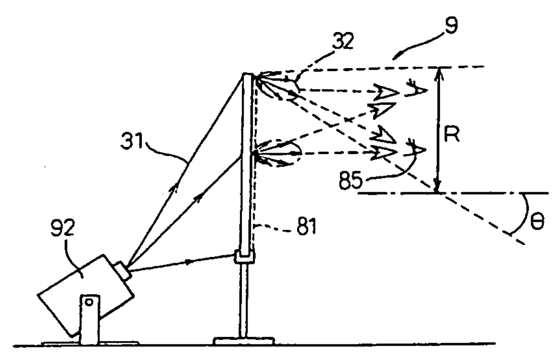
(72) Inventors:
- Takada, Kenichiro
  Kariya-city, Aichi-pref. 448 (JP)
- Nishii, Katuyoshi
  Kariya-city, Aichi-pref. 448 (JP)
- Koike, Satoshi
  Kariya-city, Aichi-pref. 448 (JP)
- Kurokawa, Kazumasa
  Kariya-city, Aichi-pref. 448 (JP)
- Shiozawa, Masahiro,
  c/o Nippon Soken, Inc.
  Nishio-shi, Aichi (JP)
- Kanda, Tomoyuki
  Kariya-City, Aichi-pref. 448 (JP)

(74) Representative:
Klingseisen, Franz, Dipl.-Ing. et al
Patentanwälte,
Dr. F. Zumstein,
Dipl.-Ing. F. Klingseisen,
Postfach 10 15 61
80089 München (DE)

(54) Method for producing transparent type hologram

(57) Method for producing a of a transparent type hologram screen of an wide visible range. A photosensitive member 50 and a light source of a reference light are arranged on the same side of the light diffusing body. A light source of an object light is arranged on the opposite side of the light diffusing body 52, so that the light is transmitted through the light diffusing body 52, thereby generating a object light 36. A light from a light source of a reference light is reflected at the light diffusing body 52 or a member such as a half mirror or a transparent, reflective hologram element arranged at a front side of the light diffusing body.

Fig. 1



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Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a method for producing a hologram of a light transparent type and more particularly to a method for producing a hologram capable of increasing a visible area during reproduction.

2. Description of Related Art

Known in a prior art is a hologram screen, where a light emitted from an indicator is irradiated onto a transparent screen on which a hologram is formed, so that a recorded image is viewed on the screen. The transparency of the hologram allows the background to be viewed through the screen by the viewer. Thus, it is possible that this type of the hologram can be used in a customer counter of a bank or a hospital in such a manner that information on a customer or a patient is projected on the screen, while a receptionist views the customer or the patient via the transparent screen.

Such an arrangement of the hologram may also be employed at an automobile retailer, wherein a reproduction image for an advertising purpose is viewed by a customer.

Furthermore, an application is also possible as for an head-up display for an automobile, which allows a driver to see a hologram image of various information such as a vehicle speed in front of the windshield.

As for such a hologram screen, a light transparent type is known, where a projector is arranged at a back side of a hologram screen, in such a manner that a reference light is issued from the projector. A real image is created on the hologram screen, from which a diffraction light is diffracted, while the image is viewed by a viewer.

In order to produce such a hologram screen, a method is known where a light is passed through a diffusion light such as a frosted glass plate so as to obtain a diffused light as an object light (signal wave), which is cooperated with a non diffused light as a reference light (reference wave), so that a interference fringe is created on a photo-sensitive member.

It is, of course, desirable that the hologram screen has a visible area as wide as possible so that a viewer can view the hologram screen at various locations. In order to widen the visible area of the hologram screen, it is necessary to increase an expansion angle of the object light as introduced into the photo-sensitive member by, for example, increasing the size of the light diffusion body or locating the latter member at a location adjacent the photo-sensitive member.

However, production of a transparent type hologram screen of an increased visual range is difficult due to the fact that an increased incident angle of an object eight causes the reference light to be blocked by the light diffusing body, which prevents the photosensitive member from being illuminated by the reference light.

SUMMARY OF THE INVENTION

An object of the present invention is to provide a method for producing a hologram screen for a transparent type display system capable of overcoming the above mentioned difficulty in the prior art.

Another object of the present invention is to provide a method for producing a hologram screen for a transparent type display system capable of obtaining an increased visible area.

According to a general aspect of the invention, a method is provided for producing a transparent type hologram screen as a hologram produced on a photosensitive member illuminated, at its one side, by a diffused light and a non-diffused light, said method comprising the steps of:

positioning a light diffusing body on one side of the photosensitive member;
introducing a first light for causing the latter to be passed through the light diffusing body, thereby generating a diffused light, which is introduced into the photosensitive member as said object light;
introducing a second light as a diverged light to the photosensitive member as said reference light, and;
providing means for preventing the second light from being blocked by the light diffusing body, while keeping a desired incident angle of the object light to the photosensitive member.

According to the first invention, a method is provided for producing a transparent type hologram screen as a hologram produced on a photosensitive member illuminated, at its one side, by a diffused light and a non-diffused light, said method comprising the steps of:

positioning a first light path of a reference light and a photosensitive member on one side of a light diffusing body, while positioning a second light path of an object light on the opposite side of the light diffusion body, and;
introducing, via the second light path, a light for causing the latter to be passed through the light diffusing body, thereby generating a diffused light as said object light, and;
introducing, via the first light path, a light so that the latter is subjected to a regular reflection at the light diffusing body so as to provide a reflected light as said reference light.

As a result of this structure, a hologram screen for a transparent type display system of an increased visible area can be produced.

According to the first invention (Fig. 4), the light

(351) is partly subjected to a regular reflection at the light diffusing body (52) without being scattered, so that the reflected light becomes a reference light (35), while the diffused light is passed through the light diffusing body and is combined with the remaining part of the light (351) scattered at the light diffusing body, which constructs an object light (36).

In the first invention, a light source of the object light (lens 516) and a light source of the reference light (lens 515) are arranged on the opposite sides of the light diffusing body (52). Thus, an increase in the expansion angle (α in Fig. 2) of the diffused light introduced into the photosensitive member is possible, while keeping an illumination of the photosensitive member (50) by means of the reference light along the entire surface. In other words, an increase in the size of the light diffusing body for increasing the expansion angle of the object light is possible while the light path of the reference is prevented from being blocked.

Furthermore, the light diffusing body (52) can be located nearer to the photosensitive member (50) for increasing the expansion angle of the object light (36), while a blockage of the light path of the reference light is less likely over the arrangement in the prior art.

According to the second invention, a method is provided for producing a transparent type hologram screen as a hologram produced on a photosensitive member illuminated, at its one side, by a diffused light and a non-diffused light, said method comprising the steps of:

positioning a first light path of a reference light and a photosensitive member on one side of a light diffusing body, while positioning a second light path of an object light on the opposite side of the light diffusion body;
positioning a half mirror between the light diffusing body and the photosensitive member, and;
introducing, via the second light path, a light for causing the latter to be passed through the light diffusing body as well as said half mirror, thereby generating a diffused light as said object light, and;
introducing, via the first light path, a light so that the latter from its upstream side is subjected to a reflection at said half mirror so as to provide a reflected light as said reference light.

According to the second invention (Fig. 5), as similar to the first invention, the light source of the object light and the reference light are arranged on the opposite sides of the light diffusing body. Thus, the increase in the expansion angle of the object light introduced into the photosensitive member is obtained, while keeping an illumination of the photosensitive member along its entire surface by the reference light, thereby producing a hologram screen of an increased visible range.

Furthermore, an arrangement of the half mirror (11) between the light diffusing body (52) and the photosensitive member (50) allows an amount of regularly reflected light to be increased, thereby increasing the strength of the reference light. On the other hand, the strength of the object light may be reduced due to the fact that a light may be reflected at the half mirror (11). Thus, adjustment of the optical characteristic of the half mirror allows the ratio of a strength to be adjusted between the object light and the reference light.

In the third invention, a method is provided for producing a transparent type hologram screen as a hologram produced on a photosensitive member illuminated, at its one side, by a diffused light and a non-diffused light, said method comprising the steps of:

positioning a first light path of a reference light and a photosensitive member on one side of a light diffusing body, while positioning a second light path of an object light on the opposite side of the light diffusion body;
positioning a transparent Lippmann type hologram element between the light diffusing body and the photosensitive member for regenerating a non-diffused light, and;
introducing, via the second light path, a light for causing the latter to be passed through the light diffusing body as well as said Lippmann type hologram element, thereby generating a diffused light as said object light, and;
introducing, via, the first light path a light so that the latter from its upstream side is subjected to a reflection at said Lippmann type hologram element so as to provide a reflected light as said reference light.

In the third invention (Fig. 6), as similar to the first invention, an expansion angle of the object light to the photosensitive member is increased while illuminating the photosensitive member by the reference light along its entire surface. Furthermore, a Lippmann type hologram element (12) is arranged between the light diffusing body (52) and the photosensitive member (50), so that an increase in the regularly reflected light is obtained, thereby increasing the strength of the reference light. Furthermore, an adjustment of the characteristic of the Lippmann type hologram (12) allows a strength ratio to be adjusted between the reference light and the object light.

According to a fourth invention, a method is provided for producing a transparent type hologram screen as a hologram produced on a photosensitive member illuminated, at its one side, by a diffused light and a non-diffused light, said method comprising the steps of:

positioning, in light paths for a reference light and an object light, a transparent light diffusion body;
introducing, via the light path, a light for causing the latter to be passed through said light diffusing body, thereby generating a diffused light as said object light, and;
introducing, via, the light path a light for causing the

latter to be passed through said light diffusing body, thereby generating a non-diffused light as said reference light.

In the fourth invention (Fig. 8), the light source of the object light (lens 515) and the light source of the reference light (lens 516) are located on the same side of the light diffusing body (53), so that the both of the lights are passed through the light diffusing body. Thus, an increase in the expansion angle of the object light (36) is possible, while the photosensitive member (50) is, over its entire surface, illuminated by the reference light (35). Thus, a production of the hologram screen of an increased visible area is possible.

According to the fifth embodiment, a method is provided for producing a transparent type hologram screen as a hologram produced on a photosensitive member illuminated, at its one side, by a diffused light and a non-diffused light, said method comprising the steps of:

positioning, in light paths for a reference light and an object light, a transparent light diffusion body which is of a type having such a directivity that a light only in a predetermined range of an incident angle is subjected to a diffusion;
introducing, via the light path, a light at an angle in said range of the incident angle for causing the latter to be passed through said light diffusing body, thereby generating a diffused light as said object light, and;
introducing, via the light path, a light at an angle outside said range of the incident angle for causing the latter to be passed through the light diffusing body, thereby generating a non-diffused light as said reference light.

In the fifth invention, an advantage as to the wide range of the visible area which is similar to the fourth invention is obtained. Furthermore, in the fifth invention, the light sources for the object and reference lights are separated, which makes it easy to adjust the strength ratio between the reference light and the object light.

According to a sixth invention, a method is provided for producing a transparent type hologram screen as a hologram produced on a photosensitive member illuminated, at its one side, by a diffused light and a non-diffused light, said method comprising the steps of:

positioning, in light paths for a reference light and an object light, a Fresnel type hologram element on which a light diffusion body is recorded, said Fresnel type hologram element being produced, first, by illuminating a photosensitive plate from its one side by a diverging light as a reference light and a diffused light as an object light for generating a hologram and, then, by forming the plate to a curved shape projected toward said light path for the incident direction of the reference and object lights;
positioning the light sensitive element on the side of a center of a curvature of the curved shape;
introducing, via the light path, a light for causing the latter to be passed through said Fresnel type hologram element, thereby generating a diffused light as said object light, and;
introducing, via, the light path a light for causing the latter to be passed through said Fresnel type hologram element, thereby generating a non-diffused light as said reference light.

In the sixth invention (Fig. 10), the Fresnel type hologram element (54) is formed with a convexed surface, which is projected toward the light sources of the reference and object lights, while the photosensitive member (50) is arranged at the side of the center of the curvature of the curve. As a result, the diffused light as the object light from a peripheral portion of the hologram element (54) is introduced obliquely to the photosensitive member (50), thereby increasing the expansion angle of the object light. Namely, in comparison with a hologram element of a flat shape, the curved shape of the hologram element (54) allows the diffused light to be directed toward the center of the curvature, thereby increasing the expansion angle of the object light, thereby making it possible to produce a hologram screen of an increased visible area.

According to the seventh invention, a method is provided for producing a transparent type hologram screen as a hologram produced on a photosensitive member illuminated, at its one side, by a diffused light and a non-diffused light, said method comprising the steps of:

positioning, in light paths for a reference light, a Lippmann type hologram element on which a light diffusion body is recorded, said Lippmann type hologram element being produced, first, by illuminating a photosensitive plate from its opposite sides by a reference light and an object light, respectively for generating a hologram and, then, by forming the plate to a curved shape projected toward said light path for the incident direction of the object light;
positioning the photosensitive member on the side of the center of the curvature of the curved shape, while positioning the light path for the object light on the side of the Lippmann type hologram element opposite to the side where the light path for the reference light is located;
introducing, via the light path, a light for causing the latter to be diffracted and reflected by said Lippmann type hologram element, thereby generating a diffused light as said object light by which the photosensitive member is illuminated, and;
introducing, via the light path a light, for causing the latter to be passed through said Lippmann type hologram element, thereby generating a non-diffused light as said reference light by which the pho-

tosensitive member is illuminated.

The seventh invention (Fig. 12) can obtain similar effect as those in the sixth invention. Namely, a position of the light source of the object light of the Lippmann type hologram element (58) is different from that by the Fresnel type hologram element. However, a similar arrangement is obtained as to the introduction of the object and reference lights with respect to the photosensitive member, and thus the function is substantially unchanged.

According to the eighth invention, a method is provided for producing a transparent type hologram screen as a hologram produced on a photosensitive member illuminated, at its one side, by a diffused light and a non-diffused light, said method comprising the steps of:

positioning, in light paths for an illuminating light a first transparent hologram element and a second transparent hologram element, the first hologram element being a Lippmann type hologram element in which a light diffusion body is recorded and having an incident surface for a hologram reproduction directed toward the photosensitive member, while the first hologram element is located on the side adjacent the light source over the second hologram element, said second hologram element being a Lippmann type hologram on which a plane mirror is recorded, said second hologram having an incident surface for a hologram reproduction which is opposite the photosensitive member, while the second hologram element is located on the side adjacent the photosensitive member, and;
introducing, via the first and second holograms, a light so that the light partly passes through the first and second holograms without being diffused for constructing a reference light, the light being partly, after the transmission of the first hologram element, diffracted and reflected at the second hologram element to the first hologram element, whereat the light is further subjected to a diffraction for forming a reflected light, which becomes a object light, thereby producing a hologram screen by a single light beam.

In the eighth invention (Fig. 14), an increase in the size of the hologram element (55) as a light diffusing body may cause the expansion angle of the object light to be easily increased. Furthermore, a location of the light diffusing body (55) nearer to the photosensitive member (50) also causes the expansion angle of the object light to be increased. Thus, production of a hologram screen of an increased visible area is possible.

According to the ninth invention, a method is provided for producing a transparent type hologram screen as a hologram produced on a photosensitive member illuminated, at its one side, by a diffused light passed through a light diffusing body and a non-diffused light, said method comprising the steps of:

introducing a light for causing the latter to be passed through the light diffusing body, thereby generating a diffused light as an object light;
introducing a light directly to the photosensitive member without making it to be passed through the light diffusion body, and;
providing an reflective optical element located at the end of the light diffusion body on the side where the reference light is introduced into the photosensitive member, the reflective optical element being extended from said end toward the photosensitive member in such a manner that light introduced at an angle opposite to the angle where the reference light forms with respect to a normal line to the light incident surface of the photosensitive member is deflected to a direction of the photosensitive member;
a part of the diffused light passed through the light diffusing body being partly subjected to a reflection at the reflective optical element, so that the reflected light is directed to the photosensitive member.

In the ninth invention (Fig. 16), the reflective optical element (14) is projected from the end of the light diffusing body (54) to the photosensitive member (50), so that the diffused light passed through the light diffusing body is reflected toward the photosensitive member. Furthermore, an operation for generating a object light is identical to the case where the end of the light diffusing body (52) is extended. Thus, an increase in the expansion angle of the object light is obtained, while preventing the reference light from being blocked by the light diffusing body. Thus, a hologram screen of an increased visible area is obtained.

In a tenth invention, said reflective optical element is partly transparent for making a light to be partly passed therethrough, part of the diffused light passing through the light diffusing body being subjected to a reflection at the reflective optical element and then being introduced into the photosensitive member, while the light from the source of the reference light passed through reflective optical element is partially or entirely introduced into the photosensitive member.

In tenth invention, the reflective optical element can transmit the incident light which increases the freedom of arrangement of the reference light. Thus, the expansion angle of the object light can be increased, thereby easily producing a hologram screen of an increased visible range.

According to an eleventh invention, a method is provided for producing a transparent type hologram screen as a hologram produced on a photosensitive member illuminated, at its one side, by a diffused light passed through a light diffusing body and a non-diffused light, said method comprising the steps of:

introducing a light for causing the latter to be passed through the light diffusing body, thereby generating a diffused light as an object light;

introducing a diverge light directly to the photosensitive member without passing it through the light diffusion body, as a reference light, and;

providing a convex lens at a front surface of the photosensitive member, thereby increasing an incident angle of the photosensitive member.

In eleventh invention (Fig. 41), an effect is obtained, which is the same as that is obtained when the size of the light diffusing body is increased or the light diffusing body is located nearer. Thus, a hologram screen of an increased visible area is produced. In this invention, the reference light is usually passed through the convex lens (66). Thus, a some measure is necessary compensate for an increase in the diverging angle of the reference light.

According to the twelfth invention, a method is provided for producing a transparent type hologram screen as a hologram produced on a photosensitive member illuminated, on its one side, by a diffused light passing through a light diffusing body, and a non-diffused light, said method comprising the steps of:

introducing a light for causing the latter to be passed through the light diffusing body, thereby generating a diffused light as an object light;

introducing a diverged light directly to the photosensitive member without making it to be passed through the light diffusion body, as a reference light and;

providing an object lens on a small opening on said light diffusing body, so that the object light is formed by a diverging light passed through said object lens.

In the twelfth invention (Fig. 42), the light source of the reference light is formed as a beam, which is passed through the lens (67) for generating a diverged reference light. Thus, the reference light is substantially prevented from being weakened by the light diffusing body. Thus, a loss of the reference light is reduced, and a design of the light path is easy and sufficient reference light is easy to provide. In particular, in the case where the diverging point of the reference light is located near to the photosensitive member, i.e., the light source of the projecting light of the screen is located near to the screen, it is possible that the light diffusing body is located closer to the photosensitive member. Thus, a hologram screen of an increased visible area can be easily produced.

According to a thirteenth invention, a method is provided for producing a transparent type hologram screen as a hologram produced on a photosensitive member illuminated, at its one side, by a diffused light passed through a light diffusing body and by a non-diffused light, said method comprising the steps of:

introducing a light for causing the latter to be passed through the light diffusing body for generating a diffused light as an object light;

introducing a diverged light as a reference light directly to the photosensitive member without making it pass through the light diffusion body, and;

providing a Fresnel type hologram element in front of the photosensitive member, so that the angle of the diffracted light with respect to the normal line of the outlet surface of the diffracted light is smaller than the angle of the illuminated light with respect to the normal line of the inlet surface.

In the thirteenth invention (Fig. 32), the Fresnel type hologram element (622) is provided, so that the incident diverging light (351) is diffracted to a diverging light (352). Thus, an increase in the incident angle (βi) of the reference light is obtained, thereby increasing the size of the light diffusing body, resulting in an increase in the visible area of the hologram screen.

According to a fourteenth invention, a method is provided for producing a transparent type hologram screen as a hologram produced on a photosensitive member illuminated, at its one side, by a diffused light passed through a light diffusing body and a non-diffused light, said method comprising the steps of:

introducing a light for causing the latter to be passed through the light diffusing body, thereby generating a diffused light as an object light;

introducing a diverged light directly to the photosensitive member without passing it through the light diffusion body, as a reference light and;

providing a Fresnel type hologram element at a location adjacent to the end of the light diffusing body adjacent the side where the reference light is introduced into the photosensitive member, said Fresnel type hologram element being projected from the light diffusing body to the photosensitive member, the arrangement of the Fresnel type hologram element being such that the reference light introduced into the Fresnel type hologram element is subjected to the diffraction toward the photosensitive member.

In the fourteenth invention (Fig. 33), by a desired adjustment of the characteristic of the Fresnel type hologram element (624), the incident angle or an aperture angle of the reference light during the hologram formation as well as the projecting direction or aperture angle during the hologram reproduction can be suitably adjusted. In relation to this, a degree of freedom of a setting of a optical system for the object light is also increased, thereby increasing a range of the incident angle of the object light, resulting in an increase in the visible range of the hologram screen.

In the fifteenth invention, a method is provided for producing a transparent type hologram screen as a

hologram produced on a photosensitive member illuminated, at its front side, by a diffused light passed through a light diffusing body and a non-diffused light, said method comprising the steps of:

introducing a light for causing the latter to be passed through the light diffusing body, thereby generating a diffused light as an object light;
introducing a diverging light directly to the photosensitive member without making it to be passed through the light diffusion body, and;
providing a Fresnel type hologram element at a front surface of the photosensitive member, on which a light diffusion body is recorded of such a directivity that allows a first light in the direction of the diverging light to be passed through in a straight manner, while a second incident light from the different direction is diffused;
the reference light being constructed by the diverging light passed through the Fresnel type hologram element;
the object light being constructed by the first object light which is a diffused light passed through the light diffusing body and then through the Fresnel type hologram element and a second object light which is the diffused light passed through the light diffusing body and diffracted at the Fresnel type hologram element.

In the fifteenth invention (Fig. 34), the diffused light is constructed by the first diffused light (first object light) as generated by the light diffusing body (52) and passed through Fresnel type hologram element (63) and a second diffused light (second object light) as generated by the Fresnel type hologram element (63). Due to the provision of the second diffused light, a function which is identical to the increase in the incident angle of the object light is obtained. Namely, an effect is obtained, that is equivalent to the one obtained when the size of the light diffusion body is spatially increased. Thus, a hologram screen of an increased visible area can be obtained.

According to a sixteenth invention, a method is provided for producing a transparent type hologram screen as a hologram produced on a photosensitive member illuminated, at its one side, by a diffused light passed through a light diffusing body and a non-diffused light, said method comprising the steps of:

introducing a light for causing the latter to be passed through the light diffusing body, thereby generating a diffused light as an object light;
introducing a diverging light directly to the photosensitive member without making it pass through the light diffusion body, and;
providing a prism between the light sources of the reference and the object lights, the prism having boundaries of a desired respective characteristic for reflection or transparency such that the direction of the diffused light passed through the light diffusion body is changed at the corresponding boundary of the prism to a desired direction as the object light, while the diverging light is deflected to a desired direction at the corresponding boundary of the prism as the reference light.

In the sixteenth invention (Fig. 36), the use of the prism (65) allows the light path and the light strength to be suitably adjusted. For example, by varying the apex angle of the prism or angle between the boundaries of the prism a desired direction of the deflection of the light is obtained. Furthermore, an adjustment of the reflectivity as well as a degree of the transmission at the boundary allows that the strength of the light to the photosensitive member to be varied. Namely, the shape of the prism and a coating on the desired boundary allow the direction of the light and the strength to be adjusted. Thus, a degree of the freedom of the direction of the reference light to the photosensitive member is increased, so that an incident angle of the object light onto the photosensitive member can be increased. Thus, a hologram screen of an increased visible area can be easily produced.

BRIEF EXPLANATION OF ATTACHED DRAWINGS

Fig. 1 is a schematic view of a display system using a hologram screen according to present invention.

Fig. 2 is a schematic view illustrating a method for producing a transparent type hologram screen in the prior art.

Fig. 3 is partial view of Fig. 2 and illustrates a blockage of a reference light by a light diffusing body.

Fig. 4 is a schematic view illustrating a method for producing a transparent type hologram screen according to a first embodiment of the present invention.

Fig. 5 is a partial schematic view illustrating a method for producing a transparent type hologram screen according to a second embodiment of the present invention.

Fig. 6 is a partial schematic view illustrating a method for producing a transparent type hologram screen according to a third embodiment of the present invention.

Figs. 7A and 7B illustrate, respectively, a distribution of a strength and a divergence of a reference light or object light.

Fig. 8 is a partial schematic view illustrating a method for producing a transparent type hologram screen according to a fourth embodiment of the present invention.

Fig. 9 illustrates a method for an exposure of a hologram used in Fig. 8.

Fig. 10 is a partial schematic view illustrating a method for producing a transparent type hologram screen according to a sixth embodiment of the present

invention.

Fig. 11 illustrates a method for an exposure of a hologram used in Fig. 10.

Fig. 12 is a partial schematic view illustrating a method for producing a transparent type hologram screen according to a seventh embodiment of the present invention.

Fig. 13 illustrates a method for an exposure of a hologram used in Fig. 12.

Fig. 14 is a partial schematic view illustrating a method for producing a transparent type hologram screen according to an eighth embodiment of the present invention.

Fig. 15 is a partial schematic view illustrating a method for producing a transparent type hologram screen according to a ninth embodiment of the present invention.

Fig. 16 is a partial schematic view illustrating a method for producing a transparent type hologram screen according to a tenth embodiment of the present invention.

Fig. 17 is a partial schematic view illustrating a method for producing a transparent type hologram screen according to a eleventh embodiment of the present invention.

Fig. 18 is a partial schematic view illustrating a method for producing a transparent type hologram screen according to a twelfth embodiment of the present invention.

Fig. 19 illustrates a reproduction image by a hologram screen using elemental holograms produced by the method in Fig. 18.

Fig. 20 illustrates a production image of a screen as an assembly of the elemental holograms produced by the method in Fig. 18.

Fig. 21 is a partial schematic view illustrating a method for producing a transparent type hologram screen according to a thirteenth embodiment of the present invention.

Fig. 22 is a partial schematic view illustrating a method for producing a transparent type hologram screen according to a fourteenth embodiment of the present invention.

Fig. 23 is a partial schematic view illustrating a method for producing a transparent type hologram screen according to a fifteenth embodiment of the present invention.

Fig. 24 is a partial schematic view illustrating a method for producing a transparent type hologram screen according to a sixteenth embodiment of the present invention.

Fig. 25 is a partial schematic view illustrating a method for producing a transparent type hologram screen according to a seventeenth embodiment of the present invention.

Fig. 26 is a partial schematic view illustrating a method for producing a transparent type hologram screen according to an eighteenth embodiment of the present invention.

Fig. 27 is a partial schematic view illustrating a method for producing a transparent type hologram screen according to a nineteenth embodiment of the present invention.

Fig. 28 is a partial schematic view illustrating a method for producing a transparent type hologram screen according to a twentieth embodiment of the present invention.

Fig. 29 is a partial schematic view illustrating a method for producing a transparent type hologram screen according to a twentieth embodiment of the present invention.

Fig. 30 is a partial schematic view illustrating a method for producing a transparent type hologram screen according to a twenty-first embodiment of the present invention.

Fig. 31 is a partial schematic view illustrating a method for producing a transparent type hologram screen according to a twenty-second embodiment of the present invention.

Fig. 32 is a partial schematic view illustrating a method for producing a transparent type hologram screen according to a twenty-third embodiment of the present invention.

Fig. 33 is a partial schematic view illustrating a method for producing a transparent type hologram screen according to a twenty-fourth embodiment of the present invention.

Fig. 34 is a partial schematic view illustrating a method for producing a transparent type hologram screen according to a twenty-fifth embodiment of the present invention.

Fig. 35 is schematic view illustrating a method for an exposure of a Fresnel type hologram in Fig. 34.

Fig. 36 is a partial schematic view illustrating a method for producing a transparent type hologram screen according to a twenty-sixth embodiment of the present invention.

Fig. 37 is a partial schematic view illustrating a method for producing a transparent type hologram screen according to a twenty-seventh embodiment of the present invention.

Fig. 38 is a partial schematic view illustrating a method for producing a transparent type hologram screen according to a twenty-eighth embodiment of the present invention.

Fig. 39 is a schematic view illustrating a light path of an object light in a prism in the twenty-eighth embodiment in Fig. 38.

Fig. 40 is a schematic view illustrating a light path of a reflected light at a mirror coat for generating a second object light in the twenty-eighth embodiment in Fig. 38.

Fig. 41 is a partial schematic view illustrating a method for producing a transparent type hologram screen according to a twenty-ninth embodiment of the present invention.

Fig. 42 is a partial schematic view illustrating a

method for producing a transparent type hologram screen according to a thirtieth embodiment of the present invention.

DESCRIPTION OF PREFERRED EMBODIMENTS

Fig. 1 shows schematically a display system to which the present invention is applied. Namely, a reference numeral 8 is a transparent type hologram screen which is to be produced in accordance with the method of the present invention. A projector 92 is arranged at a back side of the hologram screen 8, in such a manner that a reference light 31 from the projector 92 is emitted. A real image 81 is created on the hologram screen 8, from which a diffraction light 32 is diffracted, while the image 81 is viewed by a viewer 85.

Fig. 2 schematically illustrates a conventional system for production of the hologram screen of a transparent type used for the display system in Fig. 1. A reference numeral 51 denotes a coherent light source such as a laser device. A coherent light 34 from the laser light source 51 is, after a change in direction at a mirror 511, introduced into a half mirror 512, where the light is divided into beams 341 and 342. The first beam 341 is, after being diverted at a lens 516, passed through a light diffusion body 52, thereby providing a diffused light as an object light 36 when irradiated onto a photo-sensitive member 50. On the other hand, the second light 342 divided at the half mirror 512 is, after being subject to a direction change at mirrors 513 and 514, irradiated, as a reference light 35, onto the photo-sensitive member 50. Light interference occurs at the photo-sensitive member 50 between the reference light 35 and the object light 36, thereby creating interference fringes in the member 50. A hologram screen 8 as used in the system in Fig. 1 is, thus, produced. In the attached drawings, a series of corrugated lines illustrates, schematically, diffused light (waves).

In the display system in Fig. 1, the size of a visual area is defined as the area of a screen, where a viewer 85 can view an image 81 on the hologram screen 8 from different locations, i.e., a movable area R for the viewer while seeing the diffraction light 32. In order to obtain an increased visual area, it is necessary to increase an expansion angle of the object light 36 as introduced into the photo-sensitive member 50 by, for example, increasing the size of the light diffusion body 52 or locating the latter member at a location adjacent the photo-sensitive member 50. Namely, an increase in the visible area of the screen is obtained by increasing an angle α of an outer edge line 361 of the object light 36 introduced into the photo-sensitive member 50 with respect to the normal line $\underline{n}$ at the vertical ends of the photo-sensitive member 50, as shown in Fig. 2. Due to the increase in the expansion angle α of the object light during the exposure process, an increase is obtained in a visible area for allowing a viewer to see the diffused light on the screen 91 when a signal light from a projector is irradiated during a reproduction process.

However, production of a transparent type hologram screen of an increased visual range, i.e., the value of the angle α is difficult for the following reason. Namely, in the process for the exposure of the transparent type hologram screen, the reference light 35 and the object light 36 are introduced into the photo-sensitive member 50 in the identical direction as shown in Fig. 2. In order to increase the value of the angle α, a solution is conceivable that the light diffusion body is located at a position which is adjacent to the photo-sensitive member 50 or that the width W of the light diffusion body 52 is increased. However, such a solution is defective in that, as shown in Fig. 3, the reference light 35 is partly blocked by the light diffusion body 52, which causes the photo sensitive member 50 to be prevented from being illuminated at its lower part by the reference light. Even in a situation that the light may be transmitted through the light diffusion body, the transmitted light is subjected to diffusion, which will stop the light to function as a reference light.

Now, a method for producing a hologram screen for overcoming the above mentioned difficulty according to the first embodiment of the present invention will be explained. In Fig. 4, a light sensitive member 50 is, from its one side, illuminated by a diffused light as well as non-diffused light so as to create a hologram. A light diffusing body 52 is arranged between the photosensitive member 50 and a light source for a reference light 35. As a result, the light from the source is passed through the light diffusion body 55, so that a diffused light is generated, which is illustrated by a wave in Fig. 1 and constructs an object light (signal wave). On the other hand, light emitted from a lens 515 is subjected to a regular reflection at the light diffusion body 522, so that reference light (a reference wave) 35 is formed. As a result, an interference occurs between the object light 36 and the reference light 35, which causes interference fringes to be generated in the light sensitive member 50.

In this embodiment, the photo-sensitive element 50 includes, as a photo-sensitive agent, a photo-polymer. In place of photo-sensitive element including the photo-polymer, a photo-sensitive agent including an ammonium bichromate gelatin or a silver chloride can be used.

Furthermore, in the above embodiment, it is described that the light diffusing element 52 is constructed by a double sided frosted glass of grade #1000. However, as an alternative, the diffusing element 52 may be constructed by another kind of frosted glass, lenticular glass or opal glass.

As already explained with reference to Fig. 1, in order to increase the visible area on the hologram screen, i.e., a movable area R or angle α, wherein the viewer can see the image 81, it is essential that the range of the diffused light (diffracted light 32) diffracted from the hologram screen 8 is widened. In order to obtain the widened range of the diffracted light 32, it is

essential that an expansion angle θ of the object light 36 is increased during the exposure of the photo sensitive member 50. In order to do this, in the first embodiment shown in Fig. 1, in the diverted light 351 from the lens 515 as the light source of the reference light 35, a part of the light 351 is subjected to an regular reflection without being subjected to the scattering at the light diffusion body 52, so that the regular reflected light constructs the reference light 35. Thus, the light diverted from the lens 516 and diffused by passing through the light diffusion body 52 as well as the light emitted from the lens 515 and reflected and scattered by the light diffusion body 52 construct the object light 36.

As explained above, the lens 516 functioning as a light source of the object light 36 and the lens 515 functioning as a light source of the reference light 35 are arranged on opposite sides of the light diffusion body 52. Due to this arrangement, even if a value of the expansion angle α of the object light 36 introduced into the photo-sensitive member 50 is increased, a construction is possible that the photo-sensitive member 50 is, at its entire surface, illuminated by the reference light 35. As a result, a hologram screen 8 of an increased visible area can be easily produced.

Furthermore, according to this embodiment, the object light 36 is, in part, constructed by the light which is generated when the light 351 is reflected and scattered at the light diffusion body 52. As a result, an increased strength of the diffraction light 32 is obtained during the re-producing process, thereby increasing the brightness of the image 81 as generated on the screen.

Second Embodiment

In Fig. 5, a second embodiment is shown, which is different from the first embodiment in Fig. 1 in that a semi-transparent mirror 11 is provided on the light diffusion body 52. Namely, in the second embodiment, on one side of the light diffusion body 52, a photo-sensitive member 50 and the lens 515 as the light source of the reference light 35 are arranged. Furthermore, the semi-transparent mirror 11 is arranged on the surface of the light diffusion body 52 facing the photo-sensitive member 50.

In the operation of the second embodiment in Fig. 5, the object light 36 is constructed by the diffused light passed through the light diffusing body 52 and the half mirror 11, while the reference light 35 is constructed by the light 351 emitted from its source and subjected to a regular reflection at the half mirror 11. As a result, as in the first embodiment, the light source (lens 516) of the object light 36 and the light source (lens 515) of the reference light 35 are arranged on the opposite sides of the light diffusion body 52. As a result, irrespective of an arrangement for increasing the expansion angle α (Fig. 2) of the object light 36 introduced into the photo-sensitive member 50, the photo-sensitive member 50 is, over its entire surface, easily illuminated by the reference light 35. Thus, a hologram screen of an increased visible area is obtained.

Furthermore, in this embodiment, the arrangement of the half mirror 11 on the surface of the light diffusion body 35 causes the reflected amount of the light to be increased over that in the first embodiment, thereby increasing the strength of the reference light 35.

Furthermore, the second embodiment is advantageous in that by a suitably adjusting the reflection factor, in the light introduced into the photo-sensitive member 50, the strength ratio between the reference light 35 and the object light 36 R/O is controlled. In other words, an adjustment of a balance between the reference and object lights is possible which is advantageous in producing a hologram screen of an increased degree of a transparency.

Other constructions of the second embodiment in Fig. 4 are the same as those in the first embodiment in Fig. 1. Finally, the half mirror 11 is not necessarily contacted with the surface of the light diffusion body 52. Namely, a modification is possible that the half mirror 11 is spaced from the surface of the light diffusion body 52.

Third Embodiment

Fig. 6 shows a third embodiment of the present invention, in which, in place of the half mirror 11 in the second embodiment in Fig. 4, a hologram 12 of Lippmann type is used. In a manner well known by those skilled in this art, the Lippmann type hologram 12 functions to diffract the incident light 351 along the same light path of a diverging light as would be obtained when, on the position opposite the lens 515, i.e., symmetric with respect to the hologram 12, a lens 517 of the same characteristic is located. In this structure of the embodiment, by controlling the efficiency of the diffraction at the hologram 12, the same effect is obtained as is obtained by changing the reflection factor of the half mirror 11 in the second embodiment. In short, this embodiment can obtain a similar effect as in the second embodiment.

Furthermore, by adjusting the interference fringe recorded in the hologram 12, an angle of the reflection is varied, which allows the diverging position (lens 515) of the reference light 35 to be substantially varied with respect to the light diffusing body 52.

Furthermore, as shown in Figs. 7A and 7B, the distribution of the strength of the laser light about the central axis is expressed by a Gauss distribution. Thus, the diverging light 344, based on which the reference light 35 is generated as well as the diverging light 343, based on which the object light is generated are distributed along the Gauss distribution. Thus, the light issued from the diverging light and passed through the light diffusing body 52, i.e., the diffused light (a first object light) is also distributed along the Gauss distribution. Thus, the first object light has a decreased strength at the peripheral

portion over the central portion. On the other hand, the Lippmann type hologram element 12 has an increased diffraction efficiency at the central part over the peripheral part. Thus, the distribution of the diffraction efficiency of the reflection light is expressed substantially by a Gauss distribution. Thus, the distribution of the light passed through the Lippmann type hologram element 12 (non diffracting light) is expressed by an "inverse" Gauss distribution. Thus, the diffused light passed through the hologram element 12 and scattered at the light diffusion body 52 (second object light) is distributed along an inverse Gauss distribution. Thus, the strength of the total object light, which is the first object light as combined with the second object light, is distributed uniformly as compared with the second embodiment where only a Gauss distribution of the object light would be obtained, thereby obtaining a uniform distribution of the strength of the light on the surface of the image on the screen.

The other constructions are similar to those in the first and the second embodiments.

Fourth Embodiment

Fig. 8 shows a fourth embodiment which features a transparent light diffusing body 53 and the light source of the reference light as well as the light source of the object light are arranged on one side of the light diffusing body 53. Namely, the transparent light diffusion body 53 is arranged between the lens 515 and 516 and the photo-sensitive member 50. The exposure of the photo-sensitive member 50 is done by the diffused light passed through the light diffusing body 53 as the object light 35 and the non-diffused light passed through the light diffusing body 53 as the reference light 35.

In this fourth embodiment in Fig. 8, the light sources of both the object light 36 and the reference light 35 being located on the same side of the light diffusing body 53. Thus, as will be easily seen from Fig. 8, the entire surface of photo-sensitive member 50 is illuminated by the reference light 35 even in a situation that an arrangement is employed that the light diffusing body 53 is located adjacent to the photo-sensitive member 50 in order to increase the expansion angle α of the object light introduced into the photo-sensitive member 50 (Fig. 2). Thus, a hologram screen of an increased visible area can be produced.

Furthermore, due to the employment of an arrangement that the light diffusion body 53 is located adjacent to the photo-sensitive member 50, a reduction of the size of the light diffusion body 53 is possible, which is advantageous in reducing the amount of the illuminated light which does not serve for generation of an interference fringe, thereby enhancing the efficiency of the use of the light, resulting in a reduction of an exposure time.

In the embodiment, the light diffusion body includes a hologram element on which the light diffusion body is recorded.

In Fig. 9, for the sake of a simplicity of an explanation, the photo sensitive member 50 and the light diffusing body 53 are shown so that they are spaced from each other. However, it is desirable that the members 50 and 53 are in close contact.

Now, a method for obtaining a hologram diffusion body 53 in this embodiment will be explained. As shown in Fig. 9, a photo-sensitive member 500 and a light diffusion body 59 are arranged at a desired distance L1. The light diffusion body 59 is formed with a pin hole 591 at its central position.

In this embodiment, a photo polymer is used as for a light sensitive agent for the light sensitive member 500. However, in place of the photo polymer, any other type of light sensitive agent such as ammonium bichromate gelatin or a silver chloride can be used. As for the photosensitive member, it is desirable to use one that can provide an increased transparency of the completed hologram.

In Fig. 9, the distance L1 between the photo-sensitive member 500 and the light diffusion body is equalized to the distance between the diverging point (lens 516) of the object light 360 and the light diffusing body 53.

In the arrangement in Fig. 9, the non-diffused light passed through the pin hole 591 is subjected to a diffraction in such a manner that the light is diffused, thereby providing a reference light 391. On the other hand, a light passed through the body of the light diffusion body 59 and diffused thereat constructs a object light 392.

By an exposure of the light in the optical system in Fig. 9, a hologram as a transparent light diffusing body is obtained from the photo sensitive element 500.

Fifth Embodiment

This embodiment features a transparent light diffusion body 53 having directivity which is used in the fourth embodiment. The directivity is such that only a light as obtained when the incident light is at a predetermined incident angle is subjected to diffusion. To the light diffusion body 53 (Fig. 8), the light 360 is introduced in an angular range including the above mentioned desired angular range. A diffused light passed through the light diffusion body 53 becomes a object light 36. Furthermore, a light 350 is introduced into the light diffusion body 53 at the angle other than the predetermined diffusing angle, so that a non-diffused light as a reference light 35 is obtained. The exposure of the photo-sensitive element 50 is done. The other constructions are the same as those in the fourth embodiment.

In this embodiment, a hologram screen of an increased visible area is obtained as in the fourth embodiment.

Finally, in the this fifth embodiment using the light diffusing body 53 having directivity, it is an advantage that the strength of the reference light 35 and the object

light 36 can be varied by changing the angle of the directivity and/or the incident angle of the light 350 or 360.

Sixth Embodiment

Fig. 10 shows a sixth embodiment, wherein, in place of the light diffusion body 53 in the fourth embodiment in Fig. 8, a Fresnel lens type hologram element 54 is employed. In order to produce such a Fresnel lens type hologram element 54, in a similar way as shown in Fig. 9, first, a photo-sensitive member 500 is illuminated, in the same direction, by a diverging light as a reference light 391 and a diffused light as an object light 392, thereby obtaining a hologram. Then, a formation of the hologram is done in such a manner that a convex shape projected toward the side of the light source (515) is obtained. In this case, the distance L1 between the photo sensitive member 500 and the light diffusion body 54 is equalized to the desired focal length L2 of the curved hologram member 54 as shown in Fig. 11.

In the operation of the sixth embodiment, as shown in Fig. 11, the light diffusing body 54 is illuminated by the light 393 which is similar to the light 390 in Fig. 9, so that a diffused light (object light 36) directed, at its axis, toward the focal point F as a diffraction light of the light diffusing body 54 is generated.

Under an arrangement that a photo sensitive member 50 is arranged on the side of the center of the curvature of the curved body (hologram element 54), an exposure is done by the diffused light passed through the hologram element 54 as the object light 36 and a non-diffused light passed through the hologram element 54 as the reference light 35.

According to this embodiment, the Fresnel type hologram 54 can generate a diffused light at an increased efficiency when the light is incident at a predetermined angle. A part of the light introduced at the above mentioned predetermined angle and the most of the light introduced at an angle smaller than the predetermined angle are, generally, not subjected to a diffraction, thereby passed through the element 54, thereby generating a non diffused light.

In this embodiment, an interference fringe is obtained by the diffused light as an object light 36 and a non-diffused light as a reference light 35. The diffused light from the hologram element 54 is more likely directed to the center of the curvature, thereby obtaining an angle α greater than that obtained by a flat shape hologram element. Thus, by this embodiment, a hologram of an increased visible area can be obtained.

Seventh Embodiment

Fig. 12 shows a seventh embodiment, where, in place of the Fresnel type hologram element 54 in the sixth embodiment in Fig. 10, a Lippmann type hologram element 58 is used and the light source (lens 516 of the object light 36) and the light source (lens 515) for the reference light 35 are arranged on opposite sides of the photo-sensitive body 50.

In this embodiment, the light 360 diverted from the lens 516 is subjected to a diffraction and reflection at the Lippmann type hologram element 58 so as to obtain a diffused light as the object light, while the light 351 from the lens 515 is passed through the hologram element 58 so as to obtain a non-diffused light as the reference light 35. As a result, a similar effect as that in the sixth embodiment is obtained. Namely, similar to the Fresnel type hologram, the Lippmann type hologram can obtain similar object light 36 and the reference light 35 introduced into the photo-sensitive member 50.

In order to produce the Lippmann type hologram element 58, as shown in Fig. 13, the diffused light passed through the light diffusing body 58 as an object light 392 illuminates the photosensitive member 500 at its one side, while a parallel light as a reference light 390 illuminates the photosensitive member 500 at the other side, so that a hologram is obtained. Then, a forming of the hologram into a curved shape is done. The other construction is identical to that in the sixth embodiment.

Eighth Embodiment

Fig. 14 shows an eighth embodiment, which features first and second transparent hologram elements 55 and 13 which are arranged between a light source (the lens 516) and the photosensitive member 50. The first hologram element 55 is a Lippmann type hologram in which a light diffusion body is recorded. The second hologram element is a Lippmann type hologram in which a flat mirror is recorded. The first hologram element 55 is arranged on one side of the photosensitive member 50 away from the second hologram element 13 while the incident surface for the light for the hologram regeneration faces the photosensitive member. On the other hand, the second hologram element 13 is arranged on one side of the photosensitive member 50 away from the first hologram element 55 while the incident surface for hologram regeneration faces the light source. Thus, the illuminating light 360 is, in part, passed in a straight manner through the first and second hologram elements as a straight light (non-diffused light) as the reference light. The illuminating light 360 is, at its part, passed through the first hologram element 55, is subjected to diffraction and reflection by the second hologram element 13 and is subjected to diffraction and reflection at the first hologram element 55, so that an object light 36 is obtained.

In this arrangement, as will be easily understood from Fig. 14, an increase in the size of the hologram element 55 as a diffusion body makes the expansion angle α easily increased or the hologram element 55 as the light diffusion body can be located nearer to the photosensitive member 50 for increasing the expansion angle α of the object light 36. Thus, a hologram screen of an

increased visible area can easily be produced.

Furthermore, an adjustment of the diffraction efficiency of the hologram elements 55 and 13 can allow the strength ratio between the reference light and the object light to be easily adjusted.

Furthermore, the embodiment makes it possible that the photosensitive member is illuminated by a single beam, thereby simplifying the structure of the system for exposure and improving the efficiency of utilization of the laser light.

In Fig. 13, for the sake of the simplicity of the explanation, the photosensitive member 50 and the hologram element 13 are arranged to be spaced from the light diffusing body 53. However, a construction is possible where the members 50 and 53 are in close contact with each other.

The remaining construction is similar to that of the first embodiment.

Ninth Embodiment

Fig. 15 shows a ninth embodiment, which features use of a single light beam as a light source as in the sixth embodiment in Fig. 10. Namely, in Fig. 15, the photosensitive member 50 is illuminated by the diffused light passed through and diffracted at the Fresnel type hologram element 54 as the object light 35 and by the non-diffused light passed through the hologram element 54 without being diffracted as the reference light, thereby forming an interference fringe on the photosensitive member 50.

Tenth Embodiment

Fig. 16 shows a tenth embodiment, which features a reflective optical element 14 projected, toward the photosensitive member 50, from the end of the light diffusion body 52 on the side where the reference light 35 is directed toward the photosensitive member 5. The reflective optical element 14 functions to diffract and reflect the light introduced at an angle opposite to the angle the reference light 35 forms with respect to the normal line to the incident plane of the photosensitive member 50. As a result, a part of the diffused light passed through the light diffusion body 52 is subjected to a reflection at the reflective optical element 14 and is introduced, as the object light, into the photosensitive member 50.

In this embodiment, the reflective optical element 14 is projected toward the photosensitive member 50, from the front end of the light diffusion body 52, so as to obtain a function where the diffused light as passed through the light diffusion body 52 is reflected toward the photosensitive member 50. This function for generating the object light 35 is identical with the one obtained by extending the end of the light diffusion body 52 as shown by a dotted line 529 in Fig. 16. The provision of the reflective optical element 14 is advantageous in that the reference light 35 is not blocked as is the case when the extended part 529 of the light diffusion body 52 is provided. Thus, the embodiment in Fig. 16 is advantageous in that an increased angle of expansion of the object light is obtained while preventing the reference light 35 from being blocked. As a result, a hologram screen of an increased visible area can be produced.

The remaining construction is the similar to the first embodiment in Fig. 1.

Eleventh Embodiment

Fig. 17 shows a eleventh embodiment, which features a reflective optical element 15 which is constructed as a Lippmann type hologram element which allows a part of the light to pass therethrough while being diverged. In this arrangement of this embodiment, of the light 360 diverted by the lens 516, a part passes through and is diffracted at the light diffusing body 52, thereby forming a diffused light, which is partly reflected at the diverting optical element 15 and introduced, as a object light, into the photosensitive member 50. On the other hand, the light diverged at the lens 515 passes through the reflective optical element 15 and introduced, as a reference light, into the photosensitive member 50.

In the arrangement of this embodiment, the reflective optical element 15 allows the light 350 to pass therethrough. Thus, the flexibility of arrangement of the light source of the light 350 (lens 515) is increased compared to the tenth embodiment in Fig. 16. Furthermore, by arranging the reflective optical element 15 at a location adjacent the photosensitive member 50, the object light 36 is introduced into the photosensitive member 50 at wider angle. Thus, a further increase in the expansion angle a of the object light is obtained, thereby allowing a hologram screen of with wide visible area to be easily produced.

The other constructions are the same as those in the embodiment in Fig. 11.

Twelfth Embodiment

In an embodiment shown in Fig. 18, the position of the object light 36 is gradually moved so that a hologram screen of an increased image with a wide visible range is produced. Namely, in this embodiment, the light beam 34 is divided, by the beam splitter 512, into first and second beams 341 and 342. The light beam 342 is, via mirrors 513 and 514, diverged by the lens 515 to obtain a reference light 35. The diverging point of the reference light 35 is identical to the location of the projector 92 in the hologram screen 8 in Fig. 19. Contrary to this, the other beam 341 forms an object light on an optical system on a carriage 55 which is movable in the direction of the beam 341 as shown by an arrow. Namely, the beam 341 is, after being subjected to a change in the direction

at a mirror 516 on the carriage 55, diverted at the diversion lens 517 and is collimated by a collimating lens 518 so as to obtain a parallel light 343. The parallel light is passed through the light diffusing body 52, thereby providing a diffused light, which is condensed by the objective lens 519 to an object light 36.

In this embodiment, as shown in Fig. 18, a mask 58 is arranged on the front surface of the photosensitive member 50 for masking the member 50 other than the location for an exposure. In other words, an unnecessary portion of the object light is masked. As a result, a single elemental hologram (screen element) of a reduced area is obtained by the object light 36 and the reference light 35 passed through the mask 58. Then, the carriage 55 together with the parts, such as a mask 58 thereon is subjected to a movement along a forward or rearward direction as shown by the arrow, so that elementary holograms are successively produced.

Now, a reproduction operation will be explained with reference to one of the elemental holograms. As shown in Fig. 19, a projection of a signal light 31 including an image from a projector 92 located at the diverging point of the reference light 35 causes the elemental hologram to reproduce an image 521 of the light diffusing body. Under an action for changing a wave front by the elemental hologram 80, a reproduction of an image of the light diffusing body is done at an infinite distance L_z with an infinite magnitude S_z. Thus, a viewer 85 is able to view a reproduction only at a range of the angle a_0 corresponding to the visible area.

On the other hand, in the hologram screen 8 as an assembly of the series of the elementary holograms 80 as shown in Fig. 20, a light diffusion body 520 of an increased size as an assembly of the light diffusion bodies 521 reproduced, via the respective elemental holograms, at a rear side of the screen is viewed by the viewer 85. In this case, a visible area α_0 on which the viewer 85 can view the light diffusion body 520 is determined by the diameter and a focal length of the object lens 519 during the exposure process. Namely, the visible area is determined by the range (angle $\alpha 1$) of the converged object light 36 during the exposure process. In other words, an increase in the visible area can be obtained by locating the lens near to the photosensitive member 50 in order to increase the value of the angle $\alpha 1$.

In view of the above, by controlling the ratio between the effective diameter of the lens 519 and the focal length, which is referred as the numerical aperture, a control of the visible area α_0 becomes possible. In this arrangement of the hologram screen 8, a reproduction of the light diffusing body 520 is done at an infinite point, thereby keeping an increased visible range.

In this embodiment, by moving the object light 36 as well as the mask 58, an increased size of the hologram screen as an assembly of elemental holograms is obtained.

The remaining construction is the same as that in the first embodiment.

Thirteenth Embodiment

The embodiment shown in Fig. 21 features a modification of the arrangement of the second embodiment in Fig. 5 in that the half mirror 111 is arranged slightly inclined and is spaced from the light diffusing body 52.

In this arrangement, an attenuation, which would otherwise occur by a passage of the object light 36 via the half mirror 111, is prevented. Furthermore, due to an adjustment of the position and the inclination angle of the half mirror 111, an increase in a degree of the freedom is obtained as to the arrangement of a light source and a light path in the reference light 35.

The remaining construction is the same as that in the second embodiment.

Fourteenth Embodiment

This embodiment in Fig. 22 features a modification of the arrangement of the second embodiment in Fig. 5 in that a convex mirror 112, as the half mirror 11, is used.

The use of the convex mirror allows, in order to make the reference light 35 to be introduced into the photosensitive member at the same divergence angle, the lens 351 for the reference light 351 to be located at a nearer position than the flat mirror. Furthermore, due to the desired setting of the degree of the curvature of the convexed surface and the location and the inclination angle of the mirror 112, an increased degree of a freedom is obtained as to the incident angle and the expansion angle of the reference light.

The remaining construction is the same as that in the second embodiment.

Fifteenth Embodiment

The embodiment in Fig. 23 features a modification of the arrangement of the second embodiment in Fig. 5 in that a concave mirror 113 is employed as a half mirror 11.

Due to the employment of the concave mirror 113, the light introduced into the mirror 113 is subjected to convergence and is then the introduced into the photosensitive member 50. As a result, the focal point of the reference light 35 is located at a position nearer to the photosensitive member compared to the fourteenth embodiment in Fig. 22, thereby reducing the incident distance of the reference light 35. Furthermore, similar to the fourteenth embodiment, an increased degree of the freedom is obtained as to the incident angle as well as the expansion angle of the reference light with respect to the photosensitive member.

The remaining construction is the same as that in the second embodiment.

Sixteenth Embodiment

The embodiment in Fig. 24 features a modification of the arrangement of the second embodiment in Fig. 5 in that the half mirror 11 is adhered to a transparent glass member and is arranged so that the half mirror 11 covers only a part of the surface of the light diffusing body 52.

In this arrangement, a reduction of an attenuation of the object light 36 is obtained at a portion of the light diffusing body 52 not covered by the half mirror 11, thereby obtaining an increased strength of the object light.

The remaining construction is the same as that in the second embodiment.

Seventeenth Embodiment

The embodiment in Fig. 25 features a modification of the arrangement of the sixteenth embodiment in Fig. 24 in that a reflective optical element 611 is arranged between the lens 515 and the half mirror 11 and that an arrangement of the lens 515 as a light source of the reference light 36 is such that the lens 515 does not face the light diffusing body 52.

By this arrangement, an increase in the degree of the freedom of a spatial arrangement of the light path of the reference light 35 is obtained.

As for the reflective optical element, any suitable element can be utilized, including a mirror such as a flat mirror or a concave or convex mirror or a Lippmann hologram. In case where the Lippmann hologram is employed, a characteristic such as a non-regular type of reflection or a color selectively can be obtained.

The remaining construction is the same as that in the second embodiment.

Eighteenth Embodiment

The embodiment in Fig. 26 features a modification of the arrangement of the second embodiment in Fig. 5 in that a mirror coating 612 for reflection of the light is formed at the rear side of the light diffusing body 52, while a hologram screen is produced by a single beam method.

In the operation of this embodiment, a part of the incident light 351 to the half mirror 11 is subjected to a regular reflection so that a reference light 35 is obtained, while the remaining part of the light is passed through the light diffusing body 52 and is subjected to a reflection at the mirror coating 612 so that an object light 36 is obtained.

Due to the employment of the single beam method for an exposure, the light emitted from the laser as a light source is transformed into the reference light 35 and the object light 36 without division of a light, thereby largely reducing the loss of the light and increasing the intensity during the exposure. As a result, a reduction of an exposure time is obtained, while the quality of the hologram is improved since the single beam method can easily maintain a stable condition of the system during the exposure process.

The remaining construction is the same as that in the second embodiment.

Nineteenth Embodiment

The embodiment in Fig. 27 features a modification of the arrangement of the embodiment in Fig. 19 in that a prism sheet 614 is formed with a serrated boundary surface, on which a mirror coating 615 is formed and in that the incident light is subjected to a regular reflection in the direction of the photosensitive member 50, while the diffused light (object light 36) has a center of the strength in the direction of the photosensitive member 50.

In this arrangement of the embodiment, the strength of the object light 36 directed to the photosensitive member 50 is increased to the one, which is comparable with that obtained when the diverging light is introduced into the rear side of the light diffusing body 52 opposite the photosensitive member 50 as shown in the first embodiment Fig. 4. As a result, the object light 36 directed to the photosensitive member 50 has a more uniform distribution of the light strength compared to the eighteenth embodiment in Fig. 26.

The remaining construction is the same as that in the eighteenth embodiment.

Twentieth Embodiment

The embodiment in Figs. 28 and 29 features a modification of the arrangement of the third embodiment in Fig. 6 in that a non flat mirror, such as a concave mirror or a convex mirror is recorded on the Lippmann type hologram element.

In the operation of this embodiment, a far or near adjustment of an apparent position of the light source S viewed from the photosensitive member 50 (the position of the light source of the reference light 35 for an actual formation of an interference fringe on the photosensitive member) or wider or narrower adjustment of the angle α of the reference light 35 can be desirably done. Namely, as shown in Fig. 28, the apparent position S of the light source the can be located at a far position to narrow the angle α. Contrary to this, as shown in Fig. 29, the apparent position S of the light source the can be located at a near position to widen the angle α.

This embodiment is also advantageous in that a degree of the freedom as to the spatial arrangement of the light path of the reference light 35.

The remaining construction is the same as that in the eighteenth embodiment.

Twenty-first Embodiment

This embodiment in Fig. 30 features in a modification of the arrangement of the third embodiment in Fig. 6 in that a reflective optical element 611 is arranged at a location between the lens 515 and the Lippmann type hologram element 12, while the light source (lens 515) of the reference light 35 to the photosensitive member 50 is prevented from facing the light diffusing body 52.

This embodiment is advantageous in that a degree of the freedom as to the spatial arrangement of the light path of the reference light 35 is increased as in the seventeenth embodiment.

As for the reflective optical element 611, not only a mirror such as a flat, concave or convex mirror but also an element such as a Lippmann hologram can be used. By using such a Lippmann hologram, a desired far or nearer adjustment of the apparent position of the light source S is possible.

The remaining construction is the same as that in the eighteenth embodiment.

Twenty-second Embodiment

The embodiment in Fig. 31 features a modification of the arrangement of the eighteenth embodiment in Fig. 26 in that in place of the half mirror 11, a Lippmann hologram 12 recorded with a non diffusing body and a Lippmann hologram 62 recorded with a light diffusing body are used. The light diffusing body 52 is, at the rear side of the hologram element 62, formed with a mirror coat 612.

In the operation of this embodiment, the light reflected at the mirror coat is passed through the light diffusing body 52, thereby generating diffused light. Thus, an object light 36 of an increased strength as well as an increased uniformity is obtained. As a result, an improved distributed state of the object light 36 is obtained, resulting in an improvement in a color characteristic.

The remaining construction is the same as that in the eighteenth embodiment.

Twenty-third Embodiment

This embodiment features that, in the method for executing an exposure of a transparent type hologram screen as shown in Fig. 2, a Fresnel type hologram optical element 622 is arranged on the front surface of the photosensitive member 50 as shown in Fig. 32.

The function of the Fresnel type hologram optical element 622 is such that, when diverging light 351 is introduced to the element 622 at an angle βi with respect to the normal line N, diffraction occurs in a direction corresponding to that of a diverging light 352 (the light as a continuation of the dotted light) introduced at an angle β0 with respect to the normal line N. The diverging light 352 corresponds to the reference light 35 in Fig. 2.

Due to the arrangement of the hologram 622 on the front surface of the photosensitive member 50, the diverging light 351 is subjected to a diffraction by the hologram 622 to obtain a diffraction light 352, which is, as the reference light, introduced into the photosensitive member 50. In other words, the diverging light 351 in Fig. 32 functions as the reference light 35 in Fig. 2, thereby providing an increased incident angle βi of the reference light over that β0 in the reference light 35 in Fig. 2. As a result, a increase of the size of the light diffusing body 52 for the length of E in Fig. 32 is obtained in comparison with the case with no hologram 622 in Fig. 2. Thus, an increase in the visible range of the hologram screen is obtained.

It should be noted that, during the reproduction process of the hologram screen in Fig. 32, the latter is illuminated by a light in the direction of the dotted line 352, i.e., at an angle of β0.

Furthermore, in the photosensitive member 50, a hologram is also created by the light passed therethrough without being diffracted at the hologram 622 as the second reference light. Thus, a final screen characteristic is obtained as a combination of a hologram created by the first reference light and a hologram created by the second reference light. Thus, an improvement of a color characteristic (a reproduced wave characteristic) of the hologram screen is obtained due to the fact that the characteristics of the respective holograms are combined. Furthermore, by changing the incident angle during the reproduction process of the hologram with respect to that at the exposure, a displacement of the reproducing wave length characteristic of the diffraction light is obtained. In other words, a wider range of the wave length characteristic is obtained due to the fact that the different wave length characteristic are superimposed. Generally speaking, a displacement of the wave length characteristic to a longer wave length side is obtained when the angle during the exposure is smaller than that at the reproduction process. Contrary to this, a displacement of the wave length characteristic to a shorter wave length side is obtained when the angle during the exposure is larger than that at the reproduction process.

Twenty-fourth Embodiment

The embodiment in Fig. 33 features that, in the end of the light diffusing body 52 adjacent the side where the reference light 35 shown in Fig. 2, a Fresnel type hologram element 624 is arranged so that the latter extends toward the photosensitive member 50 in such a manner that the reference light 351 as introduced into the Fresnel type hologram element 624 is diffracted toward the photosensitive member 50, thereby generating a diverging light 350 directed toward the photosensitive member 50. It should be noted that the characteristic and the arrangement of the Fresnel type hologram element 624

is such that the diverging light 350 including the light indicated by a dotted line in Fig. 33 corresponds to the reference light 35 in Fig. 2.

In this structure, by suitably adjusting the characteristic and the arrangement of the Fresnel type hologram element 624, an incident direction and an aperture angle of the reference light 351 during the exposure process as well as a direction of the projecting light and an aperture angle with respect to the screen during the reproduction process as shown by dotted line in Fig. 33, can be desirably varied. As a result, a degree of a freedom of setting an optical system constructing the object light 36 is increased. Namely, an increase in the size of the light diffusing body 52 over the length E or more in Fig. 33 compared to that in Fig. 2, thereby increases a range of an incident angle of the object light 36 to the photosensitive member 50, and thereby widens the visible area of the hologram screen.

The remaining construction is the same as that in the first embodiment.

Twenty-fifth Embodiment

This embodiment in Fig. 34 features in a method for producing a hologram screen of a transparent type wherein a transparent Fresnel type hologram element 63 is arranged at the front surface of the photosensitive member 50, while the hologram element 63 is, at its front surface, illuminated by a diverging light 351 and the diffused light 346 passed through the light diffusing body 52.

In this embodiment, the hologram element 63 is the one as obtained by the optical arrangement in Fig. 35. Namely, in this arrangement, the photosensitive member 500 is arranged at a location identical to that of the hologram element 63 in Fig. 34, in which a light diffusion body 64, of a suitable directivity, is used so that the first incident light 371 corresponding to the diverging light 351 in Fig. 34 passes without changing its direction, while the second incident light 371 in the different direction is subjected to scattering.

Then, in an arrangement shown in Fig. 34, the diverging light 351 is partly passed through the hologram element 63 as the reference light, while a light diffused at the light diffusing body 52 and passed through the hologram element 63 becomes a first object light, while the diverging light 351 partly diffused at the hologram element 63 becomes a second object light. Thus, a hologram is generated by the reference and object lights.

In order to produce the Fresnel type hologram element 63, a light diffusion body 64 (Fig. 36) is arranged transversely to the photosensitive member 500. The light diffusion body 64 has a directivity such that a light 371 in a predetermined incident direction is passed therethrough in a straight manner while providing a strong scattering property to the light in the direction other than above mentioned predetermined direction, in particular to the transversely introduced light 372. A hologram is obtained by using the light 373 passed, in a straight manner, through the light diffusion body 64 as a reference light and the scattered light 374 as the object light.

As a result, the hologram element 63 allows the diverging light 351 to partially pass as it is, so that a light having a light directivity is reproduced at a position as shown by the dotted line in Fig. 34 by a part of the diverging light 351 and allows a diffraction characteristic to be generated which allows the diffused light 362 to be directed to the photosensitive member 50. Furthermore, due to the generation of such a second diffused light 362, a function is obtained which is the same as the function which is obtained when the incident angle of the object light (diffused light) to the photosensitive member is made wider or a function is obtained which is the same as the function which is obtained when the light diffusing body 52 for the formation of the object light is extended upwardly. Thus, a hologram screen of an increased visible area is generated in the photosensitive member.

The remaining construction is the same as that in the first embodiment.

Twenty-seventh Embodiment

Fig. 36 shows an embodiment of a method for producing a hologram screen in which the photosensitive member 50 is, at the same side, illuminated by the diffused light passed through the light diffusing body 52 as a object light 36 and the diverging light 351 not passed through the light diffusing body 52 as a reference light 35, featuring that, between the light sources of the reference light 35 and object light 36, a prism 65 is arranged having boundary surfaces 651 to 653 of a desired reflectivity or transparency.

In the operation of this embodiment, the diffused light passed through the light diffusing body 52 is deflected in desired directions at the boundary surfaces 651 to 653 so as to obtain an object light, while the diverting light 351 is deflected at the boundary surface 652 to a desired direction so as to obtain a reference light and a hologram is created on the photosensitive member by the reference and object lights 35 and 36.

In more detail, a light diffusing body 52 is arranged in front of the first boundary 651 of the prism 65, a reflection film is formed on the second boundary 652 which is faced with the photosensitive member 50 and a mirror coating 661 is formed on the third boundary 653.

In this arrangement, the provision of the reflecting film coated on the second boundary allows the desired strength to be maintained, while the adjustment of the inclined angle of the second boundary 652 with respect to the photosensitive member allows the direction of the diverging light 351 to be adjusted. Furthermore, the diffused light introduced via the first boundary 651 is deflected to the direction of the photosensitive member

50 by means of the mirror coating 661, so as to be introduced into the photosensitive member 50 at a wide angle. Furthermore, the mirror coating 661 functions also to deflect the diffused light from the first boundary 651 toward the photosensitive member 50, thereby reducing the leakage of the diffused light in the direction other than to that of the photosensitive member 50. In short, an increase in an efficiency of the use of the light is obtained by the mirror coating 661.

The remaining construction is the same as that in the first embodiment.

Twenty-seventh Embodiment

In this embodiment, as shown in Fig. 37, the diverging light 351 of the first light source is introduced into the prism 65 via the third boundary 653 of the prism 65, is reflected at the first boundary 651 and is discharged from the second boundary surface 652 toward the photosensitive member. In this arrangement, the incident angle of the diffused light 351 introduced into the first boundary 351 conforms to the total internal reflection angle. Thus, substantially 100 % of the reflection of the light is obtained at the boundary 651, thereby largely reducing the loss of light.

In this embodiment, the diverging light 351 is introduced into the boundary 651, which is parallel to the light diffusing body 52, and is then subjected to a deflection and reflection to the direction of the photosensitive member 50. Thus, in comparison with the arrangement of the structure in Fig. 2, where the diverging light is directly directed to the photosensitive member, the degree of freedom of the arrangement of the light path is increased. Thus, a formation of the light path for the reference light is easy even if the size of the light diffusing body 52 is increased, i.e., the production of a hologram screen of an increased visible area is easy.

The remaining construction is the same as that in the first embodiment.

Twenty-eighth Embodiment

In this embodiment, as shown in Fig. 38, on the second and third boundary surfaces 652 and 653 of the prism 65, light diffusing bodies 522 and 523 are arranged, respectively, and, on the first boundary surface 651, a reflecting coating is formed and the arrangement of the light sources with respect to the photosensitive member 50 is such that the diverging light 351 as the first light source is subjected to a reflection at the first boundary surface 651 so as to obtain a reflection light as a reference light directed to the photosensitive member. In this arrangement, a parallel light 344 is introduced into the first light diffusing body 522 from its front surface, while, on the rear surface of the second light diffusing body 523, a prism sheet 614 having a mirror coating at a serrated boundary is arranged. A collimating lens 662 in front of the light diffusing body 522 is for converting the diverted light to a parallel light, which is introduced into the light diffusing body 522.

In Fig. 39, which is an enlarged view of the prism 65 in Fig. 38, almost of the all of the diffused light passed through the first light diffusing body 522 is subjected to a reflection at the first boundary surface 651 and is introduced into the second light diffusing body 523. The light introduced into the light diffusing body 523 is partly subjected to a scattering as shown by numerals 346 and 347, and is, via the prism 65, introduced into the photosensitive member 50 as a first object light. The remaining part subjected to a reflection at the first boundary surface 651 passes through the second light diffusing body 523, is subjected to a reflection at the serrated mirror coat 615 of the prism sheet 615, is again introduced into the second light diffusing body and is again subjected to scattering and is passed through the prism 65 as a second object light, which is introduced into the photosensitive member 50.

The serrated mirror coat 615 of the prism sheet has a stepped series of inclined surfaces as shown in Fig. 40, and the inclination is such that the light 347, which has, first, been passed through the first light diffusing body 522 without being diffused as shown by 346 in Fig. 39, is subjected to a regular reflection at the first boundary surface 65a and finally passes through the second light diffusing body without being diffused, is reflected and introduced normally to the second light diffusing body 523 as shown by 348 in Fig. 40.

The light 348 reflected at the inclined surface of the mirror coat 615 is, again, subjected to diffusion at the second light diffusing body 523, is passed through the prism 65 and is introduced into the photosensitive member as a second object light. The second light diffusing body 523 is not merely provided but is arranged so as to cooperate with the first light diffusing body 522 and the prism sheet as explained above, which results in a uniform distribution of the light introduced into the photosensitive member.

In the absence of the first light diffusing body 522, the diffused light obtained by the second light diffusing body 523 will be localized to a direction for a regular reflection of an incident light. The provision of the first light diffusing body 522 causes a diffusion of the light to be generated. In other words, a multiplicity an incident angles of the light is obtained, thereby preventing the distribution of the diffused light from being localized.

In view of the above, the first light diffusing body 522 functions to improve the distribution of the diffused light. However, in the distribution of the strength of the light reflected by the second light diffusing body 523, the strength in the direction toward the first light diffusing body 522 is still insufficient, i.e., is deviated from the desired distribution characteristic. It is the prism sheet 614 that improves the distribution characteristic. Namely, the inclined surface of the mirror coat 615 functions to transversely direct the regularly reflected light component of an increased strength to the second light

diffusing body 523. However, a suitable selection of the inclination allows the reflected light to be rotated toward the first light diffusing body 522 as shown by a dotted line. As a result, a further improvement is obtained as to a distribution of the diffused light by the second light diffusing body 523.

Furthermore, a reflection of the light by the mirror coat 615 serves to reduce a loss of the light to the outer side.

Finally, in this embodiment, the direction of the reference light 351 as the first light source and the direction of the incident light 343 as the second light source are substantially opposite. As a result, an improvement is obtained as to the degree of the freedom of the spatial arrangement of the first and second light sources, which is otherwise occurred in the arrangement in the prior art as shown in Fig. 2.

The remaining construction is the same as that in the first embodiment.

Twenty-ninth Embodiment

Fig. 41 shows an embodiment of a method for producing a transparent type hologram screen, in which the photosensitive member 50 is, at its same side, illuminated by the diffused light passed through the light diffusing body 52, as an object light emitted to the photosensitive member 50, and the diverging light 351, as a reference light not passed through the light diffusing body 52. The method features a convexed lens 66 is arranged in front of the photosensitive member 50, which is for diverging the incident light, thereby obtaining a further wider angle of the incident light to the photosensitive member.

Due to the operation of the convexed lens 66, the incident light 365 to the photosensitive member is equivalent to the light that is provided by the light 340 as shown by dotted line. As a result, an effect is obtained, which is identical to the effect which is obtained when the area of the light diffusing body is increased as shown by the dotted line or the light diffusing body is located nearer, thereby allowing a hologram screen of an increased visible area to be produced.

The remaining construction is the same as that in the first embodiment.

Thirtieth Embodiment

Fig. 42 shows an embodiment of a method, for producing a transparent type hologram screen, in which the photosensitive member 50 is, at its same side, illuminated by the diffused light passed through the light diffusing body 52 is as an object light emitted to the photosensitive member 50 and the diverging light 351 as a reference light not passed through the light diffusing body 52, featuring that the light diffusing body 52 is formed with an opening in which an object lens 67 is attached, and a light as a reference light 35 is passed through the object lens 67.

In this embodiment, a beam from a light source is transformed to a diverging light at the object lens 67 so as to provide a reference light 35. Contrary to this, a parallel light 344 is introduced into the light diffusing body 52 so that the light is passed through the light diffusing body, thereby providing a diffused light as an object light 36.

In this embodiment, the lens 67 is illuminated by a beam 350 for forming a reference light, thereby preventing the reference light from being scattered or weakened by the light diffusing body 52. As a result, a reduction in the loss of the reference light, thereby increasing a energy efficiency, makes it easy to design the light path and improves the light strength.

Furthermore, in case where the diverging point of the reference light 35 is located near to the photosensitive member, i.e., the projecting light source is located near to the screen, it makes it easy for the light diffusing body to be located near to the photosensitive member, thereby making it easy to produce a hologram screen of a wide visible range.

Finally, the location of the reproduction of the hole on the screen is equal to a position of the light source during the reproduction process. Thus, a desired function of the screen is maintained irrespective of an existence of the hole on the reproduced image.

The remaining construction is the same as that in the first embodiment.

Claims

1. A method for producing a transparent type hologram screen as a hologram produced on a photosensitive member illuminated, at its one side, by a diffused light and a non-diffused light, said method comprising the steps of:

   positioning a light diffusing body on one side of the photosensitive member;
   introducing a first light for causing the latter to be passed through the light diffusing body, thereby generating a diffused light, which is introduced into the photosensitive member as said object light;
   introducing a second light as a diverged light to the photosensitive member as said reference light, and;
   providing means for preventing the second light from being blocked by the light diffusing body, while keeping a desired incident angle of the object light to the photosensitive member.

2. A method for producing a transparent type hologram screen as a hologram produced on a photosensitive member illuminated, at its one side, by a diffused light and a non-diffused light, said method comprising the steps of:

positioning a first light path of a reference light and a photosensitive member on one side of a light diffusing body, while positioning a second light path of an object light on the opposite side of the light diffusion body, and;

introducing, via the second light path, a light for causing the latter to be passed through the light diffusing body, thereby generating a diffused light as said object light, and;

introducing, via the first light path, a light so that the latter is subjected to a regular reflection at the light diffusing body so as to provide a reflected light as said reference light.

3. A method for producing a transparent type hologram screen as a hologram produced on a photosensitive member illuminated, at its one side, by a diffused light and a non-diffused light, said method comprising the steps of:

positioning a first light path of a reference light and a photosensitive member on one side of a light diffusing body, while positioning a second light path of an object light on the opposite side of the light diffusion body;

positioning a half mirror between the light diffusing body and the photosensitive member, and;

introducing, via the second light path, a light for causing the latter to be passed through the light diffusing body as well as said half mirror, thereby generating a diffused light as said object light, and;

introducing, via the first light path, a light so that the latter from its upstream side is subjected to a reflection at said half mirror so as to provide a reflected eight as said reference light.

4. A method for producing a transparent type hologram screen as a hologram produced on a photosensitive member illuminated, at its one side, by a diffused light and a non-diffused light, said method comprising the steps of:

positioning a first light path of a reference light and a photosensitive member on one side of a light diffusing body, while positioning a second light path of an object light on the opposite side of the light diffusion body;

positioning a transparent Lippmann type hologram element between the light diffusing body and the photosensitive member for regenerating a non-diffused light, and;

introducing, via the second light path, a light for causing the latter to be passed through the light diffusing body as well as said Lippmann type hologram element, thereby generating a diffused light as said object light, and;

introducing, via the first light path, a light so that the latter from its upstream side is subjected to a reflection at said Lippmann type hologram element so as to provide a reflected light as said reference light.

5. A method for producing a transparent type hologram screen as a hologram produced on a photosensitive member illuminated, at its one side, by a diffused light and a non-diffused light, said method comprising the steps of:

positioning, in light paths for a reference light and an object light, a transparent light diffusion body, and;

introducing, via the light path, a light for causing the latter to be passed through said light diffusing body for generating a diffused light as said object light as well as for generating a non-diffused light as said reference light.

6. A method for producing a transparent type hologram screen as a hologram produced on a photosensitive member illuminated, at its one side, by a diffused light and a non-diffused light, said method comprising the steps of:

positioning, in light paths for a reference light and an object light, a transparent light diffusion body, which is of a type haying such a directivity that a light only in a predetermined range of an incident angle is subjected to a diffusion;

introducing, via the light path, a light in said range of the incident angle for causing the latter to be passed through said light diffusing body, thereby generating a diffused light as said object light, and;

introducing, via the light path, a light outside said range of the incident angle for causing the latter to be passed through the light diffusing body, thereby generating a non-diffused light as said reference light.

7. A method for producing a transparent type hologram screen as a hologram produced on a photosensitive member illuminated, at its one side, by a diffused light and a non-diffused light, said method comprising the steps of:

positioning, in light paths for a reference light and an object light, a Fresnel type hologram element on which a light diffusion body is recorded, said Fresnel type hologram element being produced, first, by illuminating a photosensitive plate from its one side by a diverging light as a reference light and a diffused light as an object light for generating a hologram and, then, by forming the plate to a curved shape

projected toward said light path for the incident direction of the reference and object lights;

positioning the light sensitive element on the side of a center of a curvature of the curved shape;

introducing, via the light path, a light for causing the latter to be passed through said Fresnel type hologram element, thereby generating a diffused light as said object light, and;

introducing, via, the light path a light for causing the latter to be passed through said Fresnel type hologram element, thereby generating a non-diffused light as said reference light.

8. A method for producing a transparent type hologram screen as a hologram produced on a photosensitive member illuminated, at its one side, by a diffused eight and a non-diffused light, said method comprising the steps of:

positioning, in a light path for a reference light, a Lippmann type hologram element on which a light diffusion body is recorded, said Lippmann type hologram element being produced, first, by illuminating a photosensitive plate from its opposite sides by a reference light and an object light, respectively for generating a hologram and, then, by forming the plate to a curved shape projected toward said light path for the incident direction of the object light;

positioning the photosensitive member on the side of the center of the curvature of the curved shape, while positioning the light path for the object light on the side of the Lippmann type hologram element opposite to the side where the light path for the reference light is located;

introducing, via the light path, a light for causing the latter to be diffracted and reflected by said Lippmann type hologram element, thereby generating a diffused light as said object light by which the photosensitive member is illuminated, and;

introducing, via the light path, a light for causing the latter to be passed through said Lippmann type hologram element, thereby generating a non-diffused light as said reference light by which the photosensitive member is illuminated.

9. A method for producing a transparent type hologram screen as a hologram produced on a photosensitive member illuminated, at its one side, by a diffused light and a non-diffused light, said method comprising the steps of:

positioning, in light paths for an illuminating light a first transparent hologram element and a second transparent hologram element, the first hologram element being a Lippmann type hologram element in which a light diffusion body is record and having an incident surface for a hologram reproduction directed toward the photosensitive member, while the first hologram element is located on the side adjacent the light source over the second hologram element, said second hologram element being a Lippmann type hologram on which a plane mirror is recorded, said second hologram having an incident surface for a hologram reproduction which is opposite the photosensitive member, while the second hologram element is located on the side adjacent the photosensitive member, and;

introducing, via the first and second holograms, light so that the light partly passes through the first and second holograms without being diffused for constructing a reference light, the light being, partly, after transmission through the first hologram element, diffracted and reflected at the second hologram element to the first hologram element, whereat the light is further subjected to diffraction for forming a reflected light, which becomes a object light, thereby producing a hologram screen by a single light beam.

10. A method for producing a transparent type hologram screen as a hologram produced on a photosensitive member illuminated, at its one side, by a diffused light passed through a light diffusing body and a non-diffused light, said method comprising the steps of:

introducing a light for causing the latter to pass through the light diffusing body, thereby generating a diffused light as an object light;

introducing a light directly to the photosensitive member without making it to pass through the light diffusion body, and;

providing a reflective optical element located at the end of the light diffusion body on the side where the reference light is introduced into the photosensitive member, the reflective optical element being extended from said end toward the photosensitive member in such a manner that a light introduced at an angle opposite to the angle where the reference light is formed with respect to a normal line to the light incident surface of the photosensitive member is deflected to a direction of the photosensitive member;

a part of the diffused light passed through the light diffusing body being partly subjected to a reflection at the reflective optical element, so that the reflected light is directed to the photosensitive member.

11. A method according to claim 10, wherein said reflective optical element comprises a transparent element for making a light to be partly passed therethrough, a part of the diffused light passed through the light diffusing body being subjected to a reflection at the reflective optical element and introduced into the photosensitive member, while the light from the source of the reference light passed through reflective optical element is partially or entirely introduced into the photosensitive member.

12. A method for producing a transparent type hologram screen as a hologram produced on a photosensitive member illuminated, at its one side, by a diffused light passed through a light diffusing body and a non-diffused light, said method comprising the steps of:

    introducing a light for causing the latter to be passed through the light diffusing body, thereby generating a diffused light as an object light;
    introducing a diverge light directly to the photosensitive member without making it to be passed through the light diffusion body, as a reference light and;
    providing a convexed lens at a front surface of the photosensitive member, thereby increasing an incident angle to the photosensitive member.

13. A method for producing a transparent type hologram screen as a hologram produced on a photosensitive member illuminated, at its one side, by a diffused light passed through a light diffusing body and a non-diffused light, said method comprising the steps of:

    introducing a light for causing the latter to be passed through the light diffusing body, thereby generating a diffused light as an object light;
    introducing a diverged light directly to the photosensitive member without making it to pass through the light diffusion body, as a reference light and;
    providing an object lens in a small opening on said light diffusing body, so that the object light is formed by a diverging light passed through said object lens.

14. A method for producing a transparent type hologram screen as a hologram produced on a photosensitive member illuminated, at its one side, by diffused light passed through a light diffusing body and non-diffused light, said method comprising the steps of:

    introducing a light for causing the latter to pass through the light diffusing body for generating a diffused light as an object light;
    introducing a diverged light as a reference light directly to the photosensitive member without making it to be passed through the light diffusion body, and;
    providing a Fresnel type hologram element in front of the photosensitive member, so that the angle of the diffracted light with respect to the normal line of the outlet surface of the diffracted light is smaller than the angle of the illuminated light with respect to the normal line of the inlet surface.

15. A method for producing a transparent type hologram screen as a hologram produced on a photosensitive member illuminated, at its one side, by a diffused light passed through a light diffusing body and a non-diffused light, said method comprising the steps of:

    introducing a light for causing the latter to be passed through the light diffusing body, thereby generating a diffused light as an object light;
    introducing a diverged light directly to the photosensitive member without making it to pass through the light diffusion body, as a reference light and;
    providing a Fresnel type hologram element at a location adjacent to the end of the light diffusing body adjacent to the side where the reference light is introduced into the photosensitive member, said Fresnel type hologram element being projected from the light diffusing body to the photosensitive member, the arrangement of the Fresnel type hologram element being such that the reference light introduced into the Fresnel type hologram element is subjected to diffraction toward the photosensitive member.

16. A method for producing a transparent type hologram screen as a hologram produced on a photosensitive member illuminated, at its front side, by a diffused light passed through a light diffusing body and a non-diffused light, said method comprising the steps of:

    introducing a light for causing the latter to be passed through the light diffusing body, thereby generating a diffused light as an object light;
    introducing a diverging light directly to the photosensitive member without making it to pass through the light diffusion body, and;
    providing a Fresnel type hologram element at a front surface of the photosensitive member, on which a light diffusion body is recorded in such a directivity that it allows a first light in the direction of the diverging light to pass through as it is, while a second incident light from a different

direction is diffused;

the reference light being constructed by the diverging light passed through the Fresnel type hologram element;

the object light being constructed by the first object light which is a diffused light as passed through the light diffusing body and then through the Fresnel type hologram element and a second object light which is the diffused light diffracted at the Fresnel type hologram element.

17. A method for producing a transparent type hologram screen as a hologram produced on a photosensitive member illuminated, at its one side, by a diffused light passed through a light diffusing body and a non-diffused light, said method comprising the steps of:

introducing a light for causing the latter to be passed through the light diffusing body, thereby generating a diffused light as an object light;

introducing a diverging light directly to the photosensitive member without making it to pass through the light diffusion body, and;

providing a prism between the light sources of the reference and the object lights, the prism having boundaries of desired respective characteristic for a reflection or transparency such that the direction of the diffused light passing through the light diffusion body is changed at the corresponding boundary of the prism to a desired direction as the object light, while the diverging light is deflected to a desired direction at the corresponding boundary of the prism as the reference light.

Fig. 1

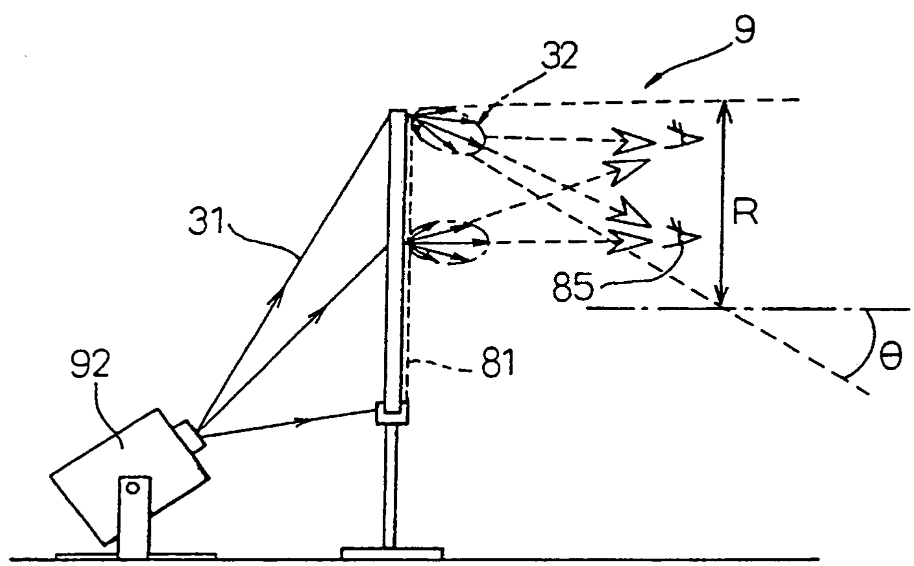

Fig.2
(PRIOR ART)

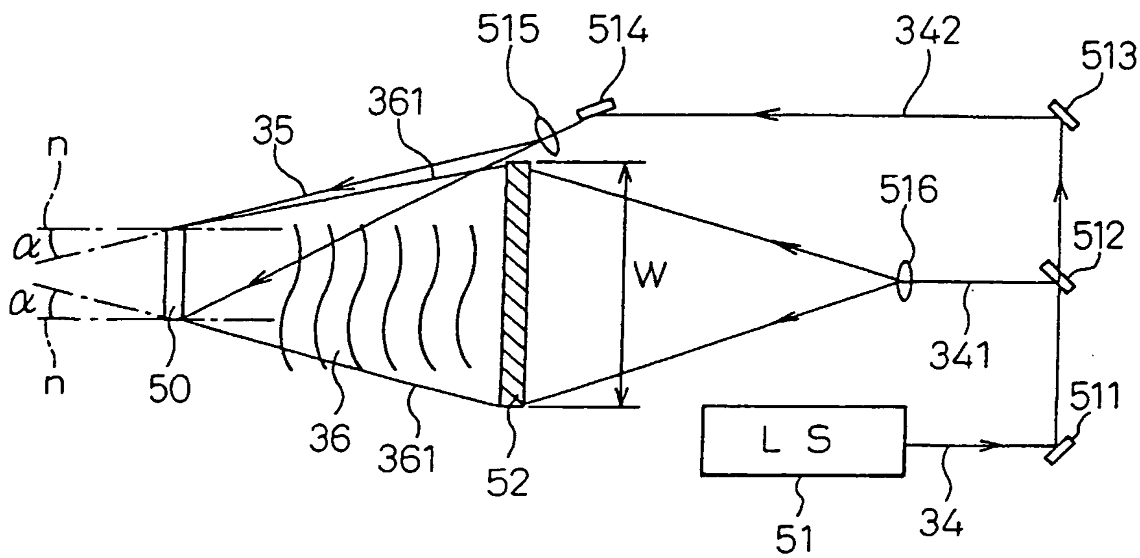

Fig.3
(PRIOR ART)

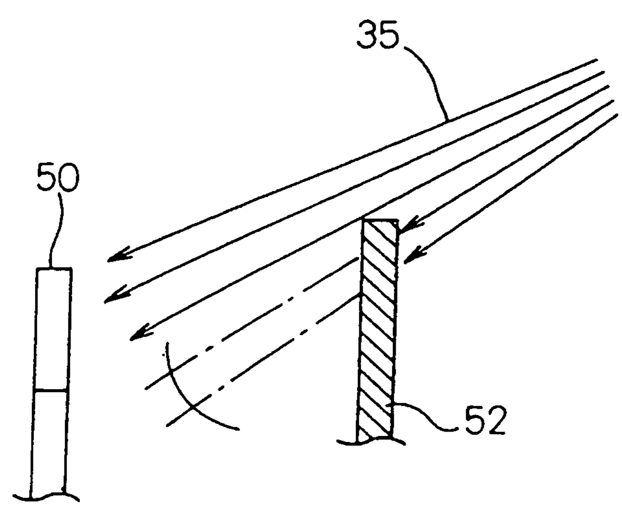

Fig. 4

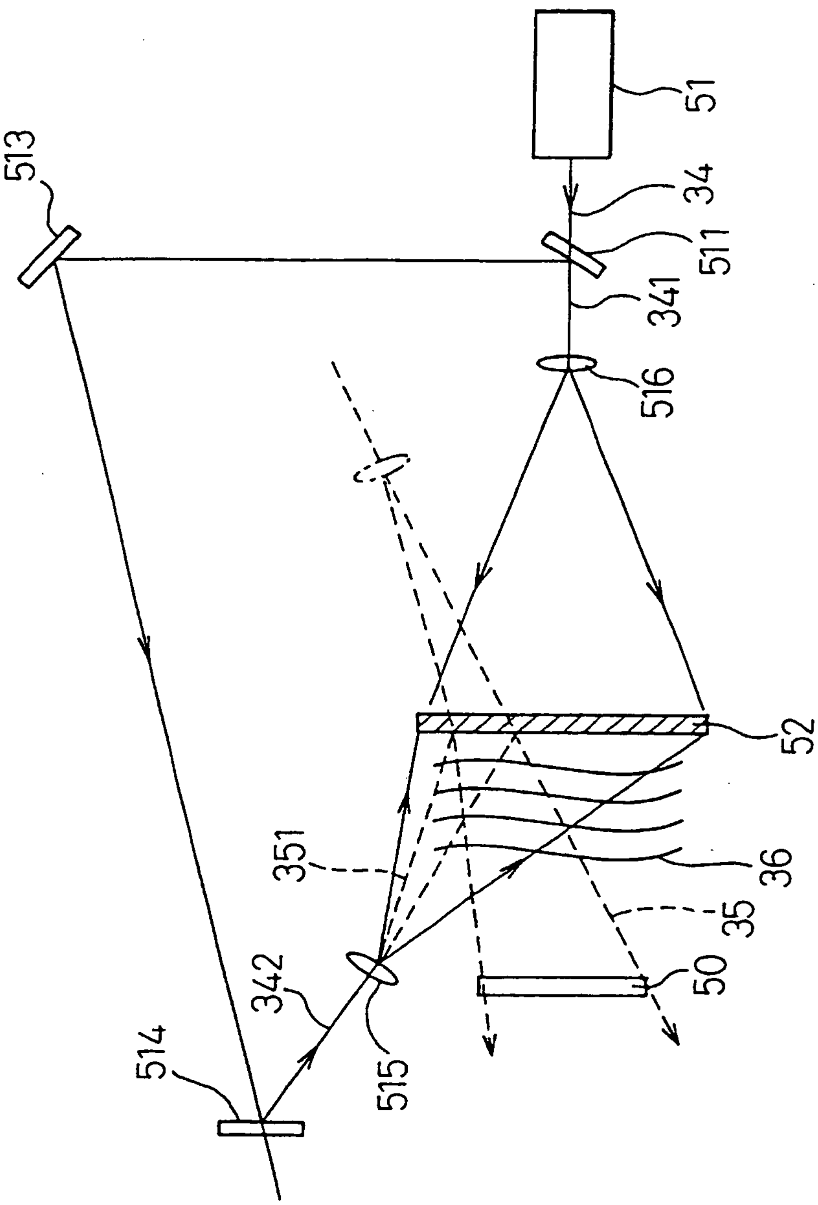

Fig. 5

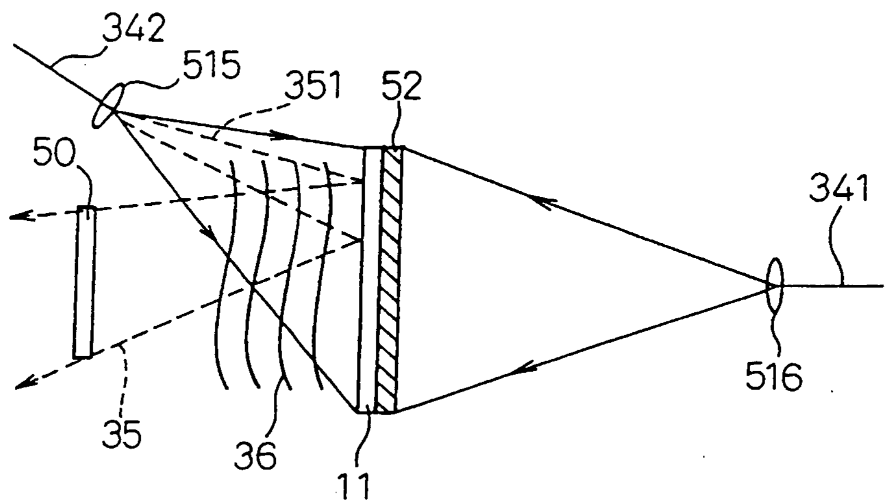
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Fig. 6

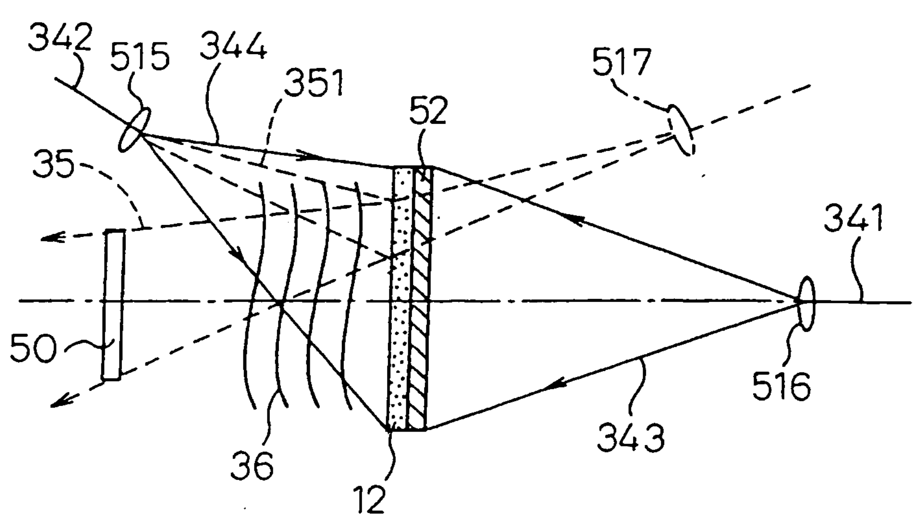
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Fig.7A

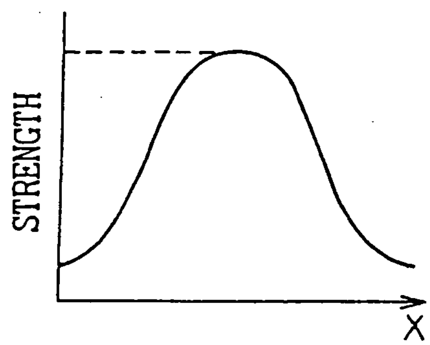


Fig.7B

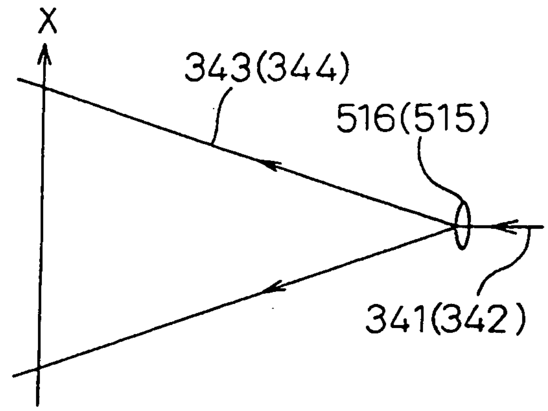


Fig.8

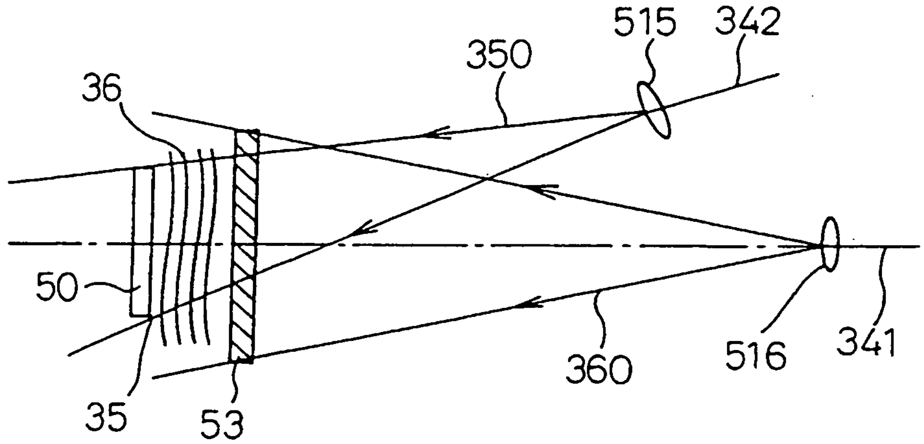


Fig.9

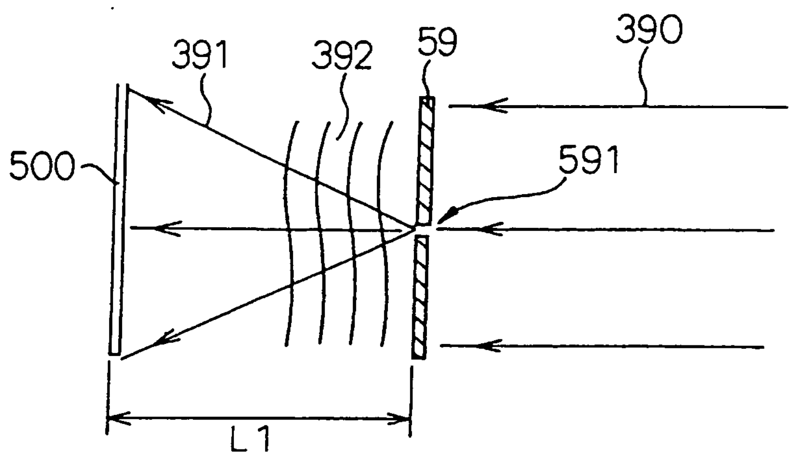


Fig.10

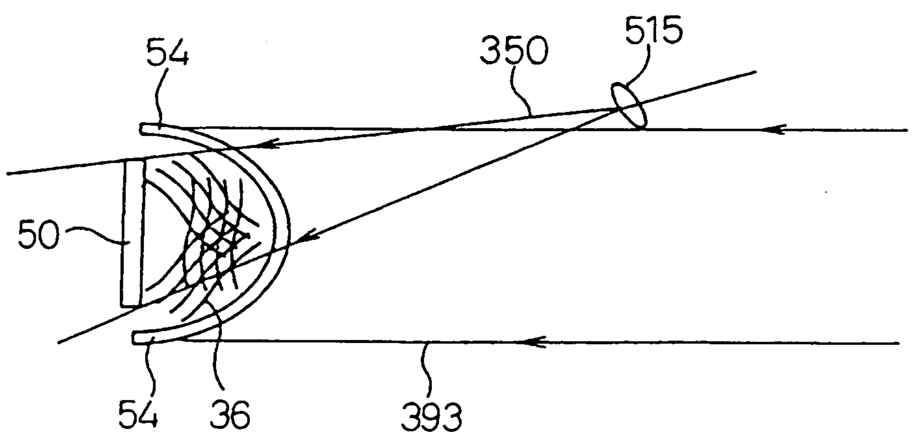


Fig.11

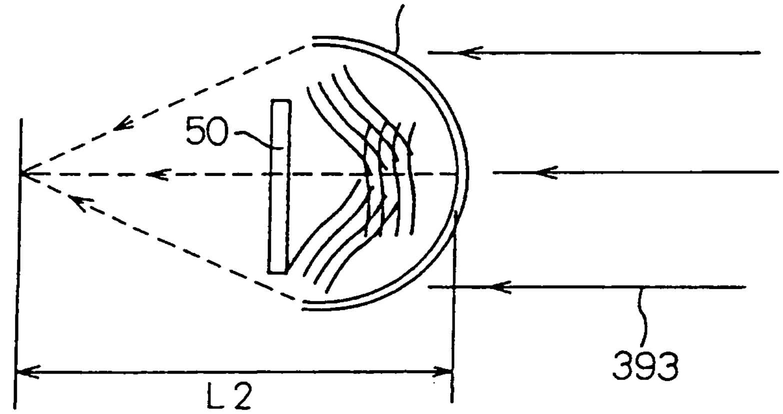


Fig.12

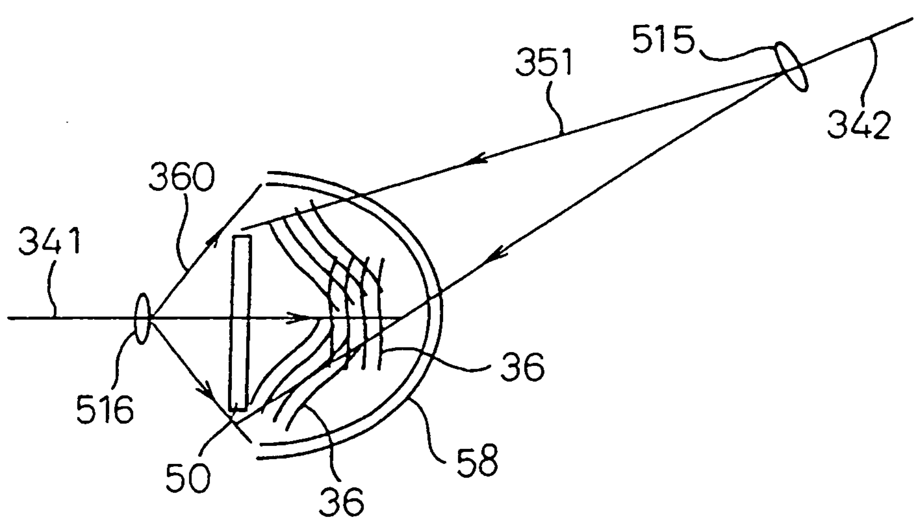


Fig.13

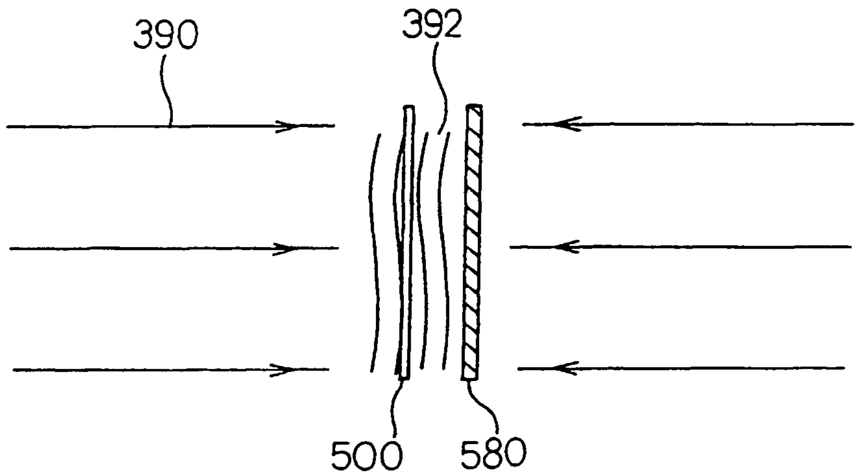


Fig.14

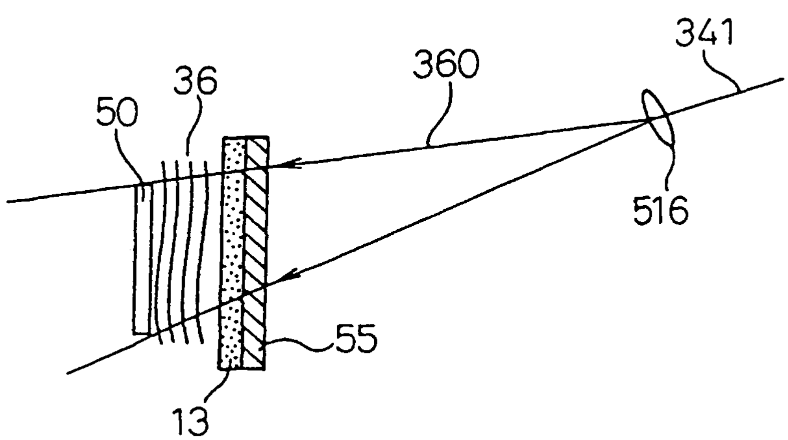


Fig.15

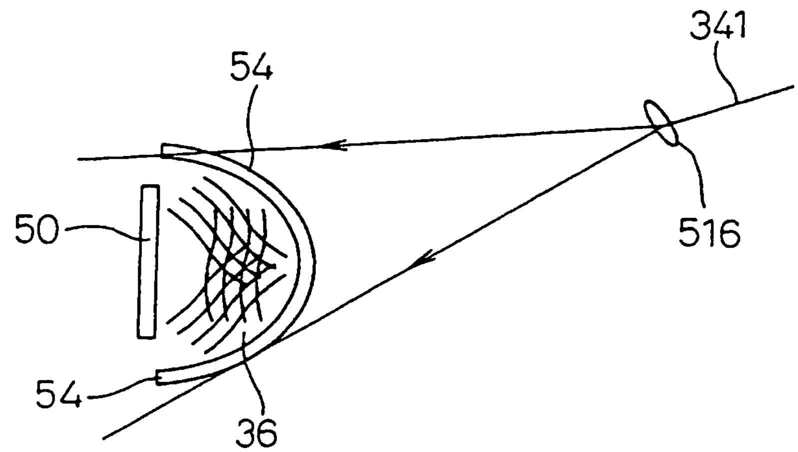


Fig.16

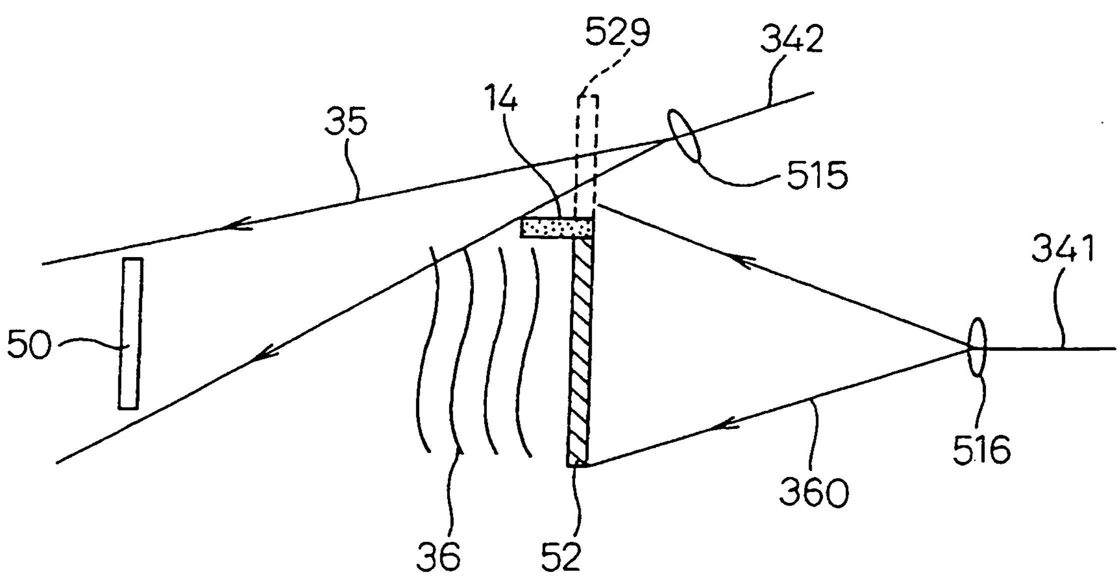
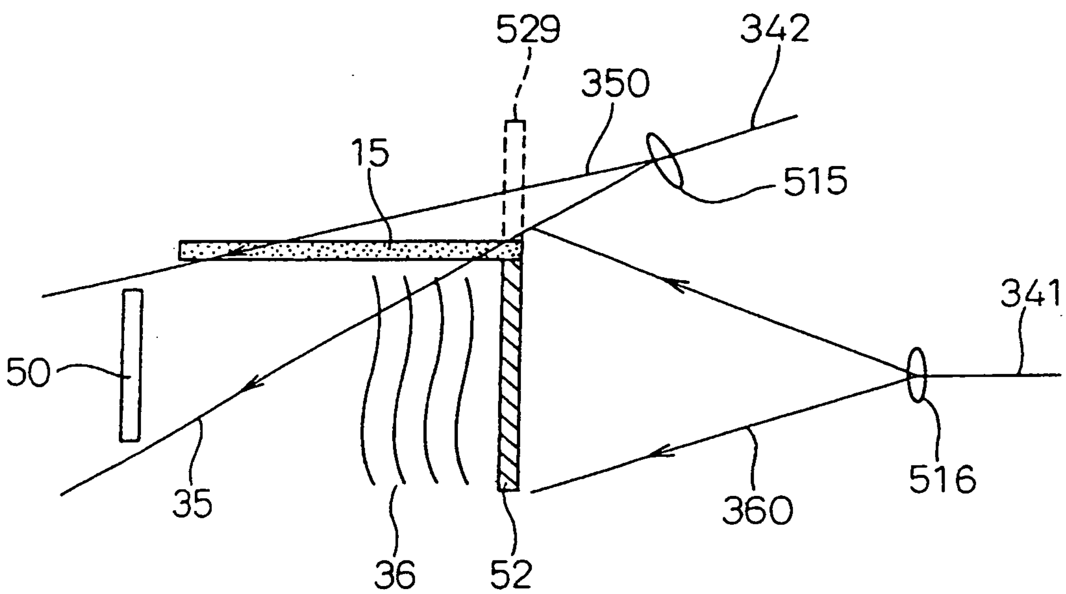


Fig.17



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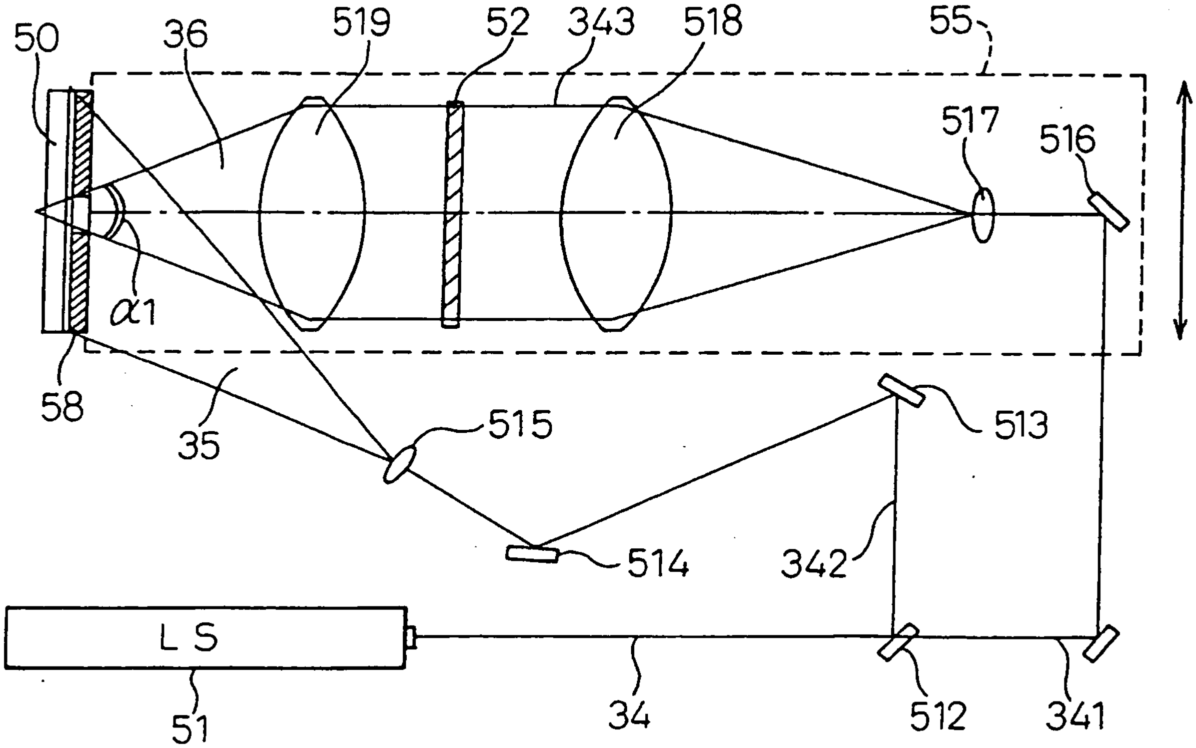
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Fig.19

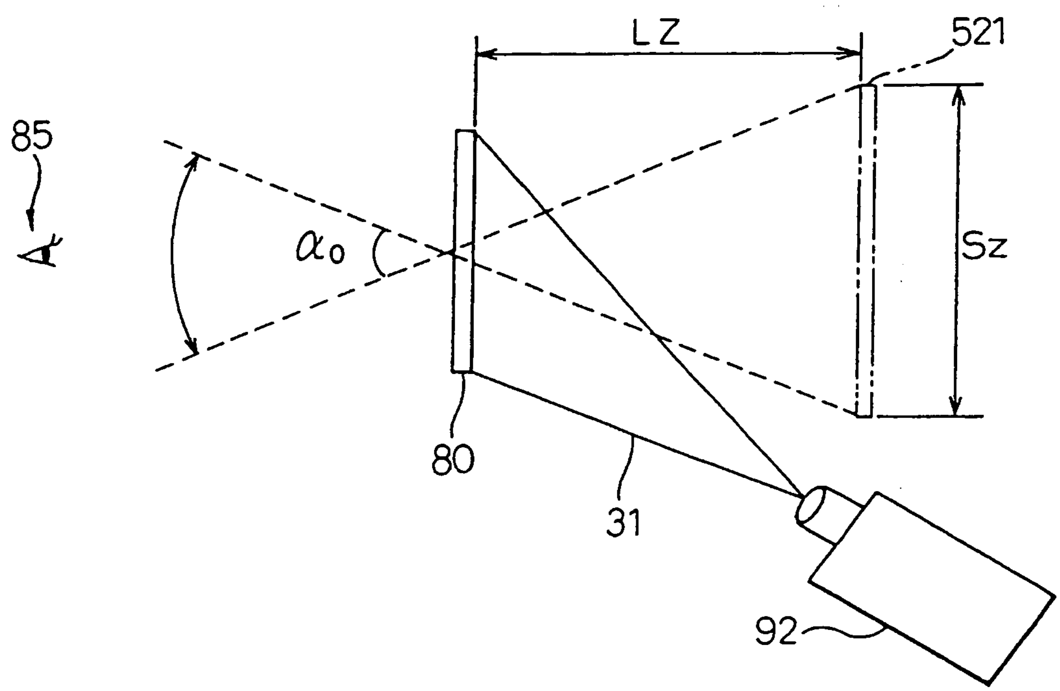


Fig. 20

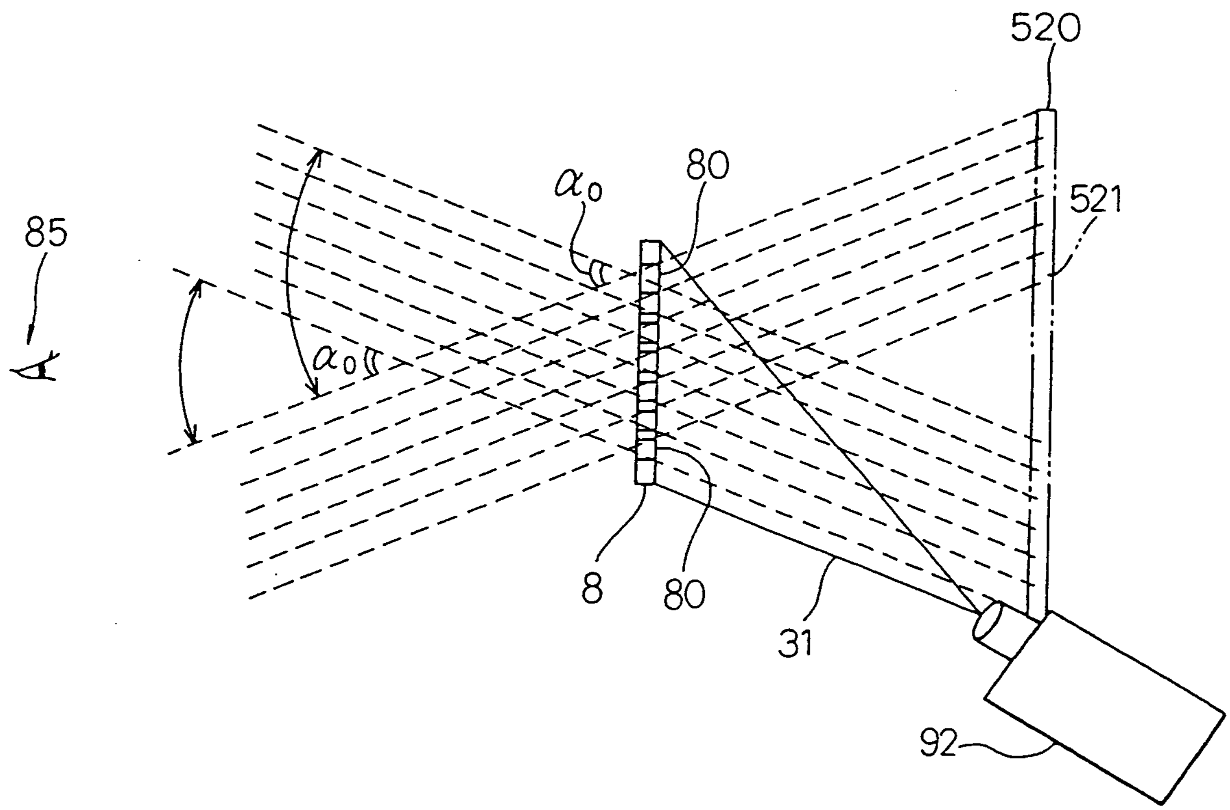


Fig. 21

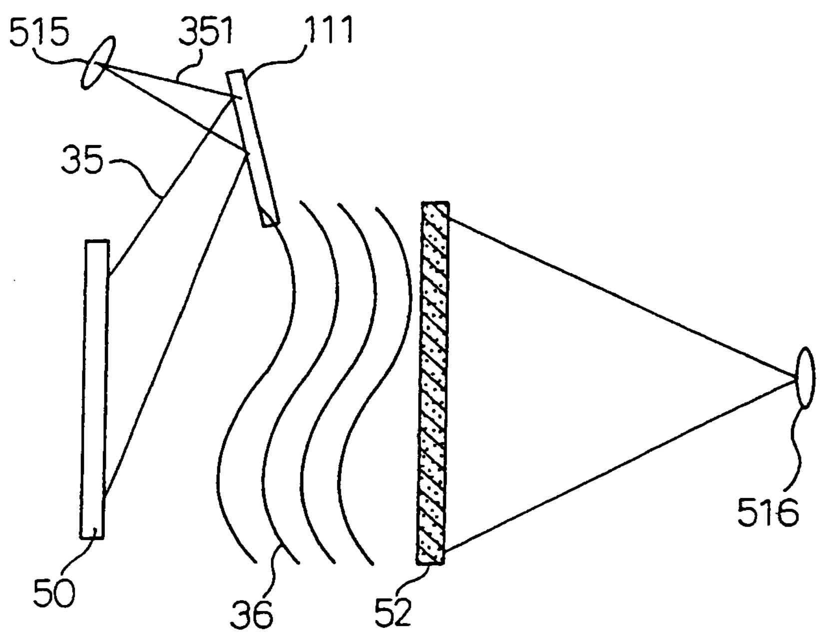


Fig. 22

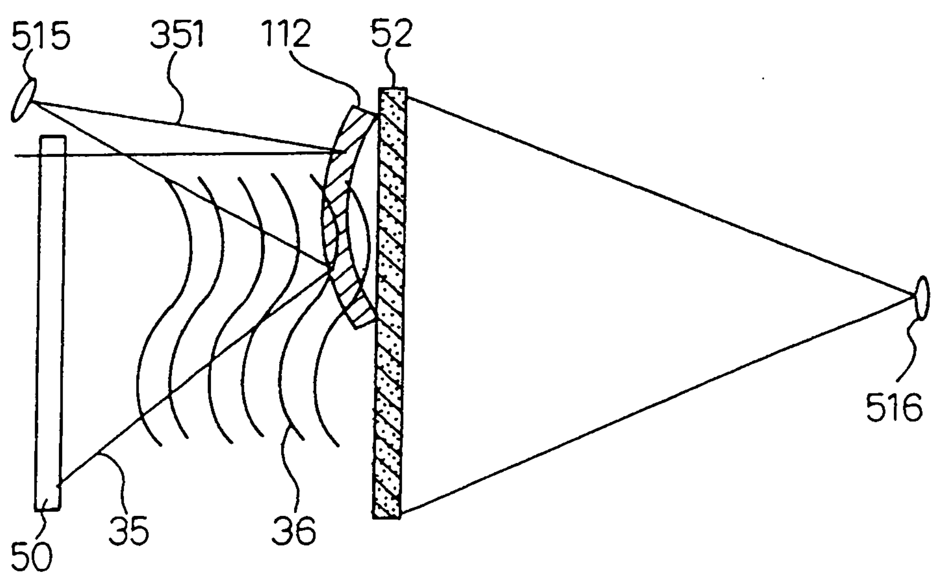


Fig. 23

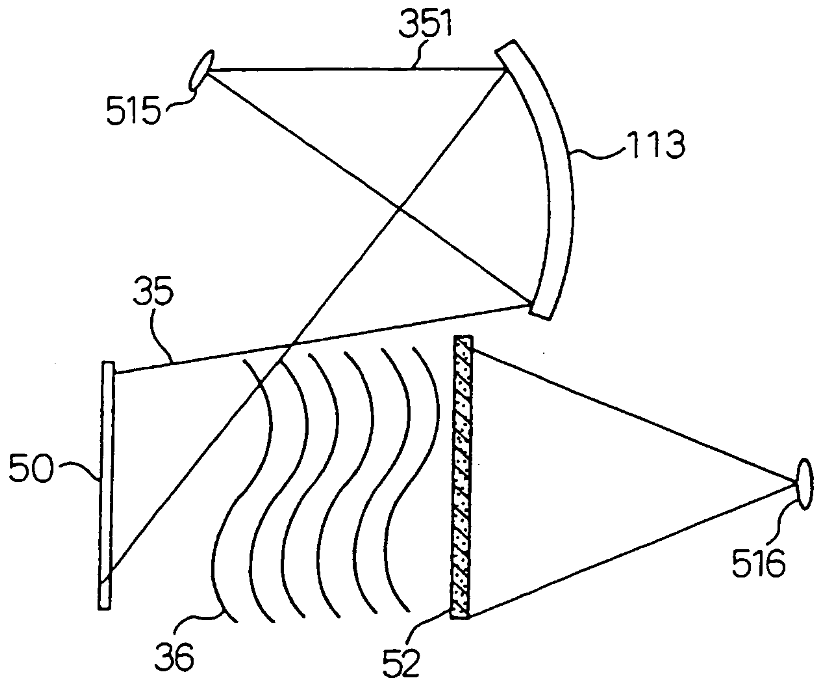


Fig. 24

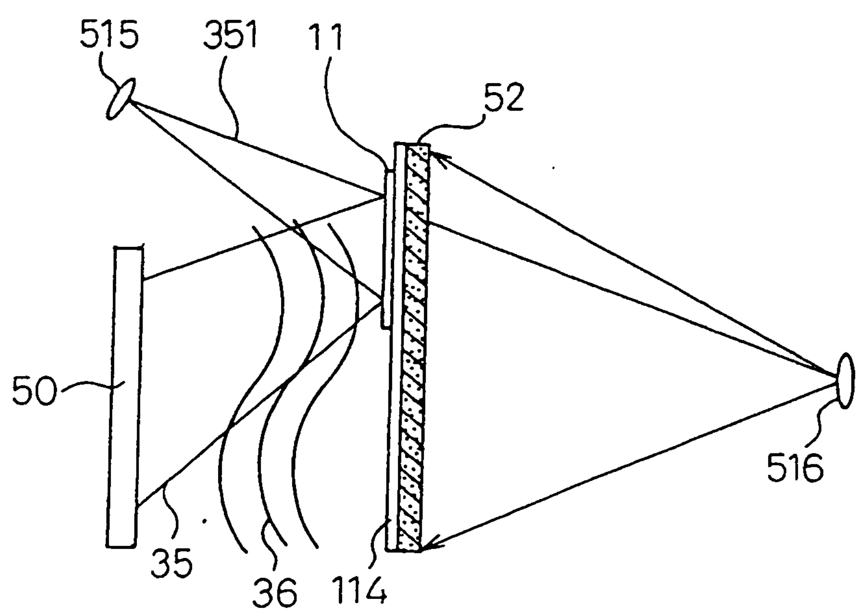


Fig. 25

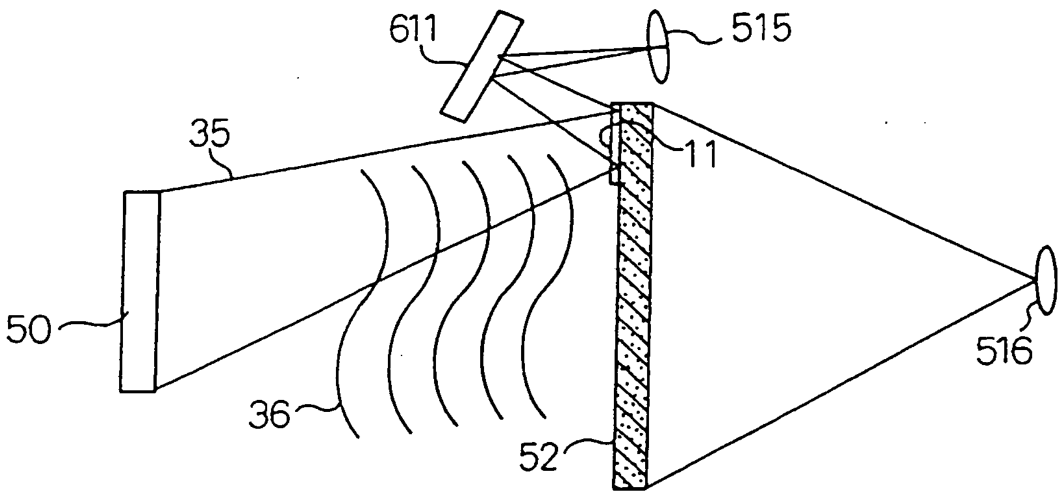


Fig. 26

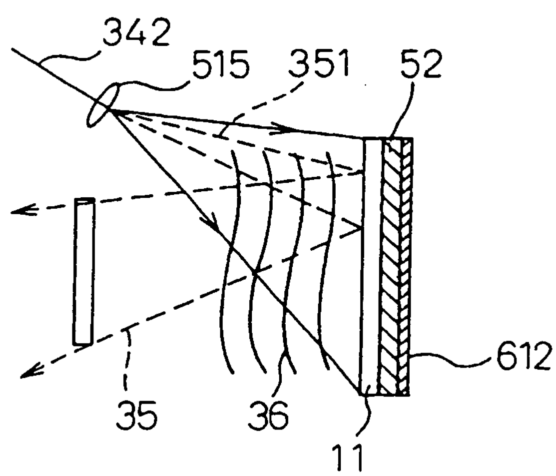


Fig. 27

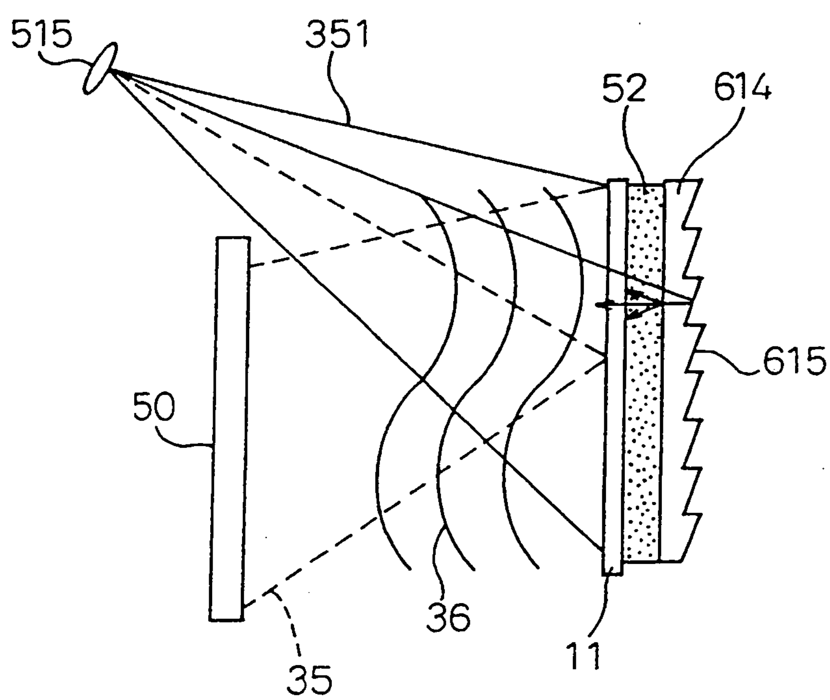
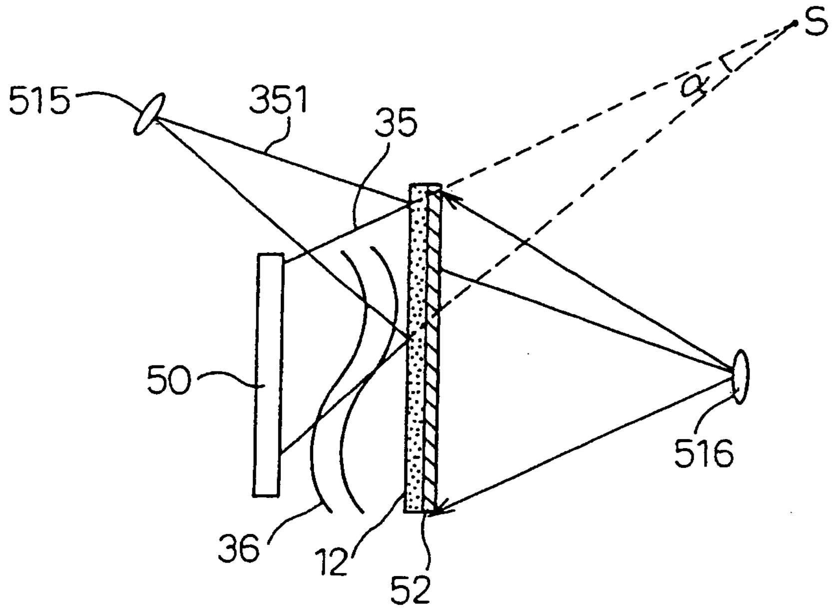


Fig. 28



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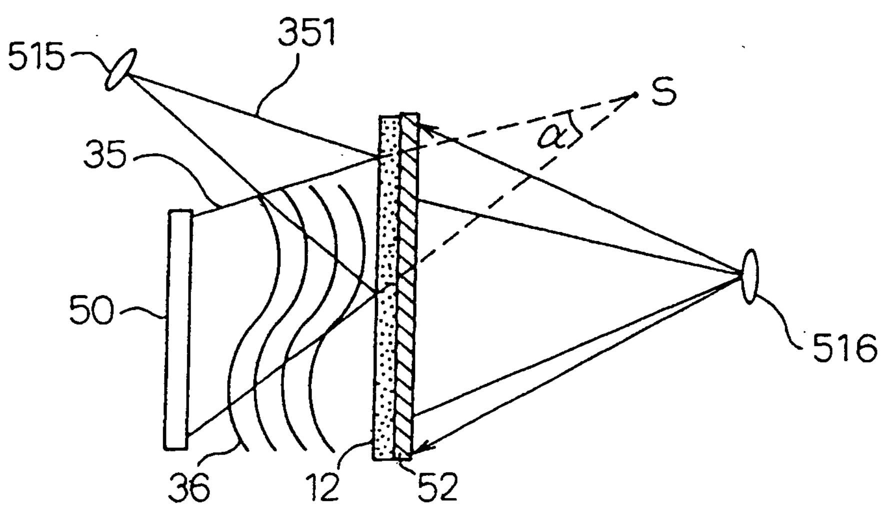

Fig.30

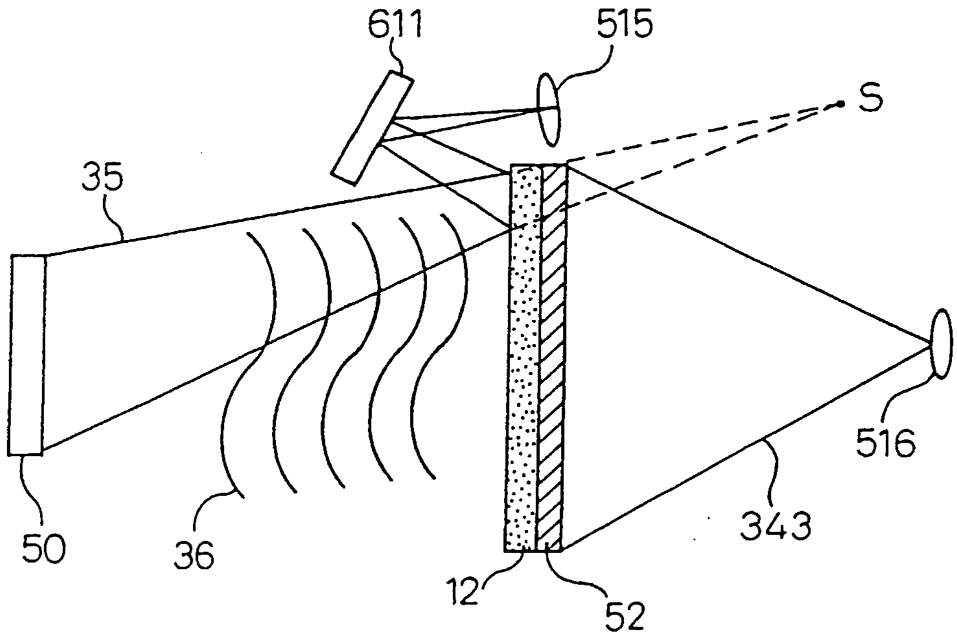

Fig.31

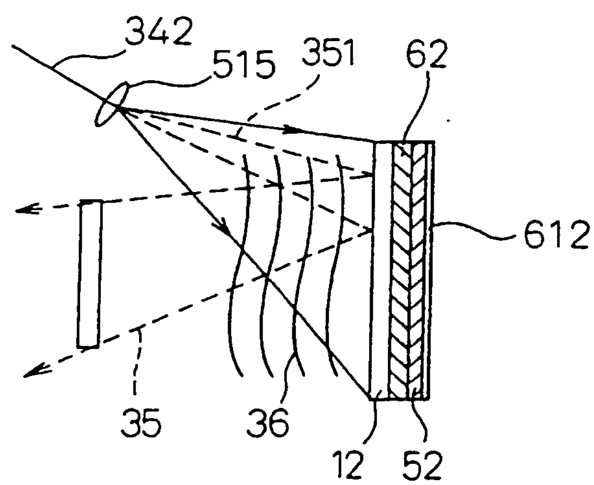

Fig. 32

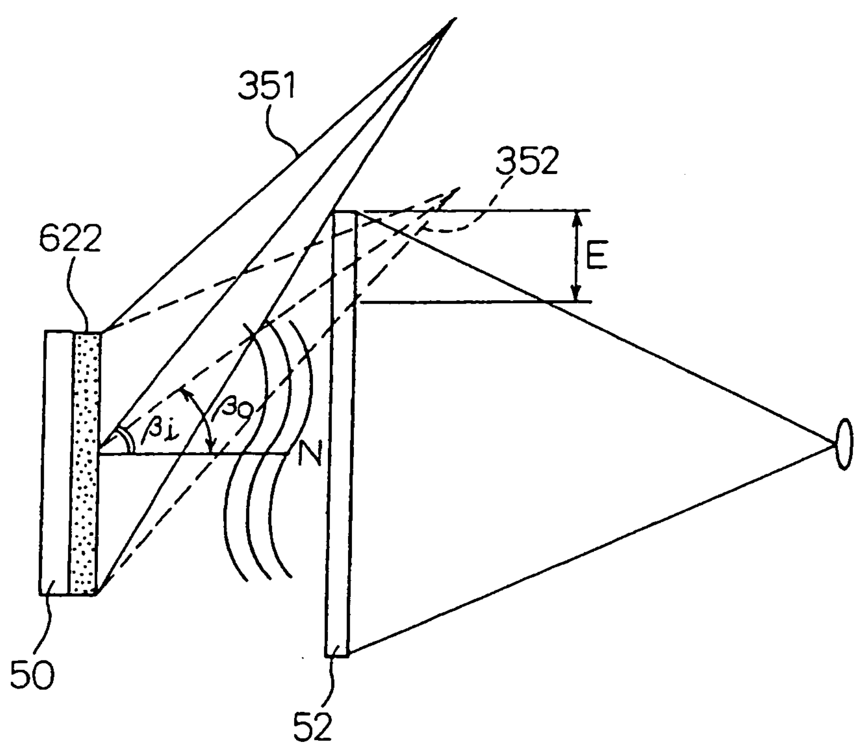

Fig.33

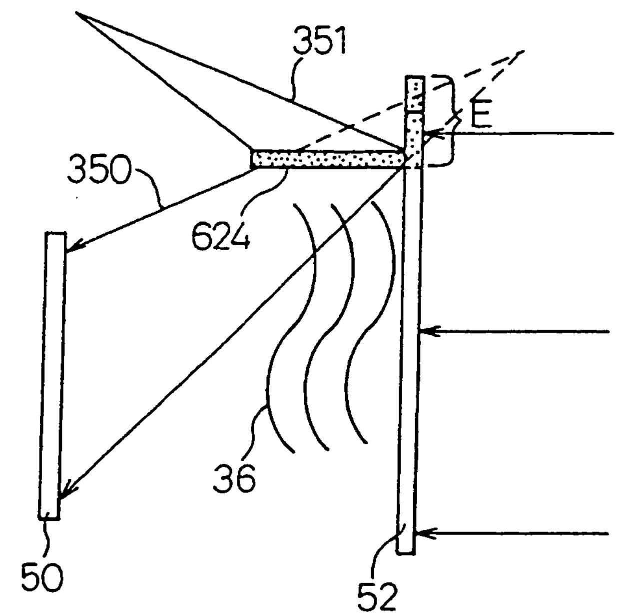

Fig.34

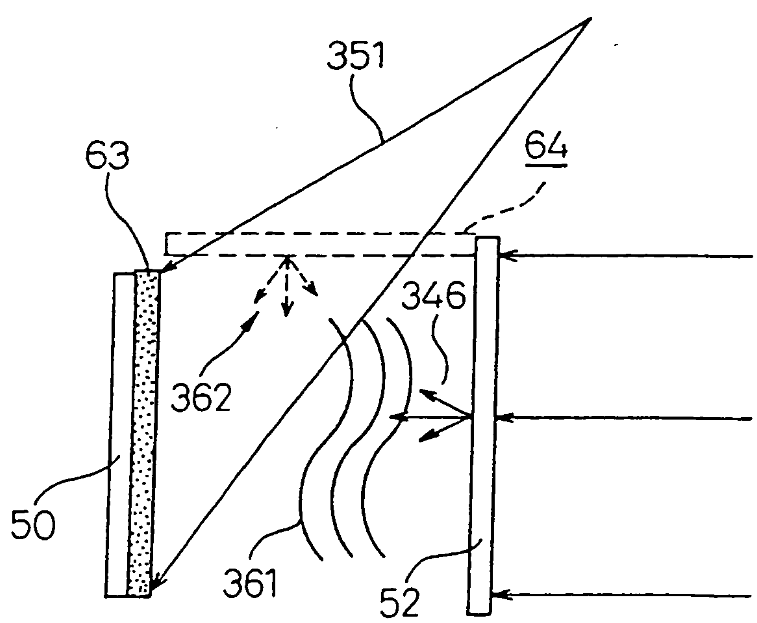

Fig. 35

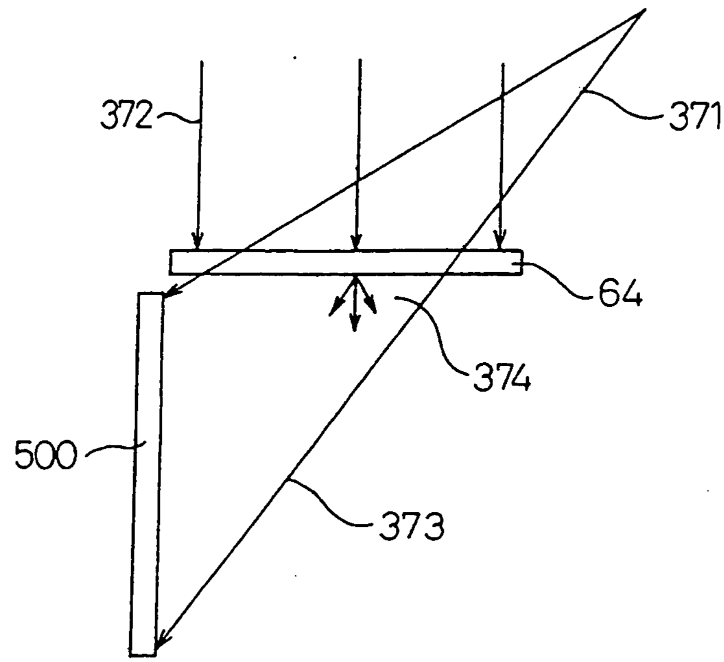

Fig. 36

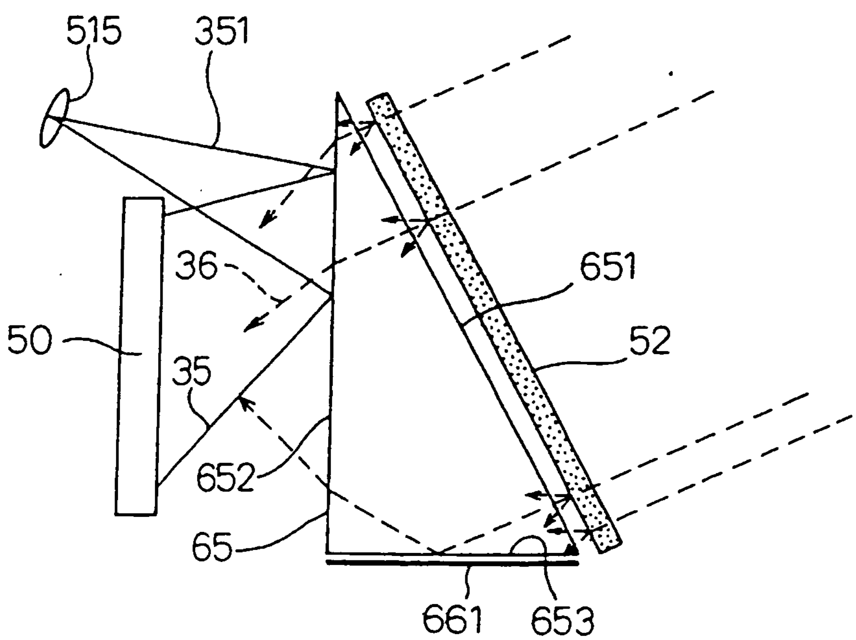

Fig.37

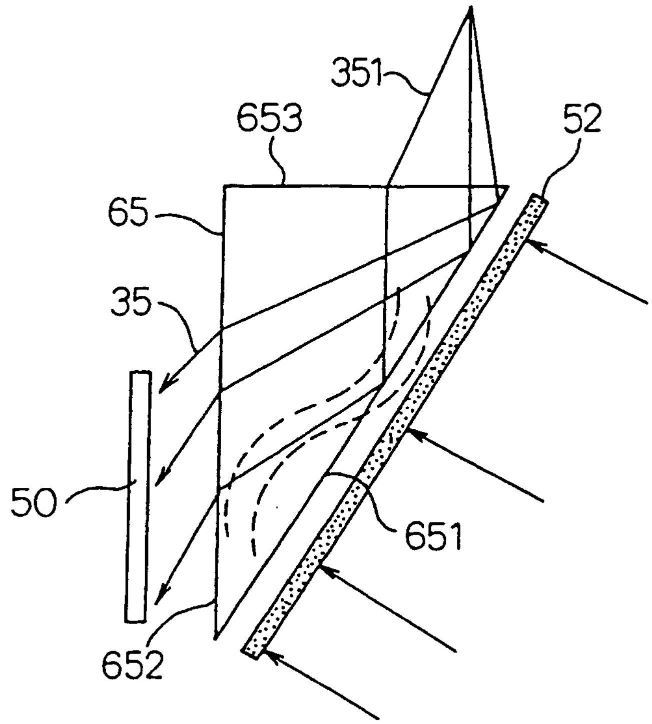
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Fig.38

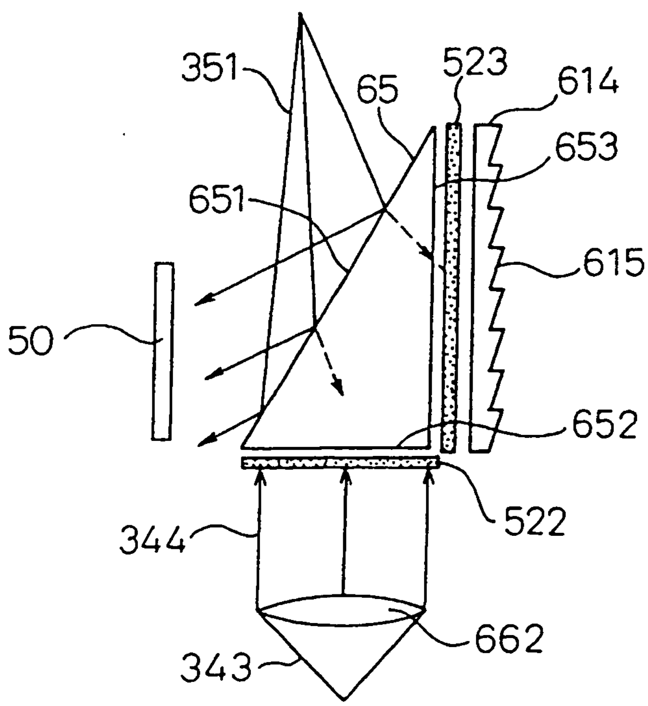
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Fig.39

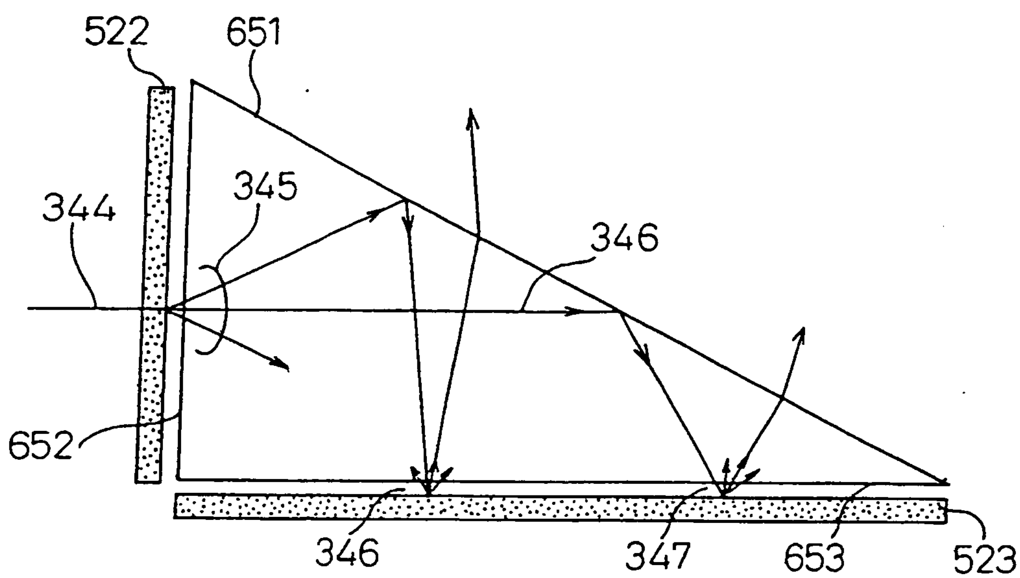
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Fig.40

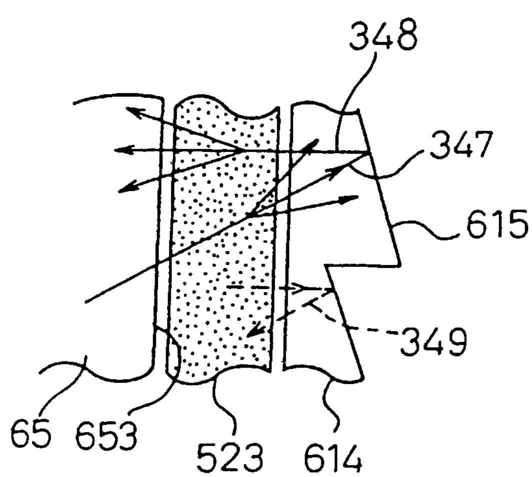
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Fig.41

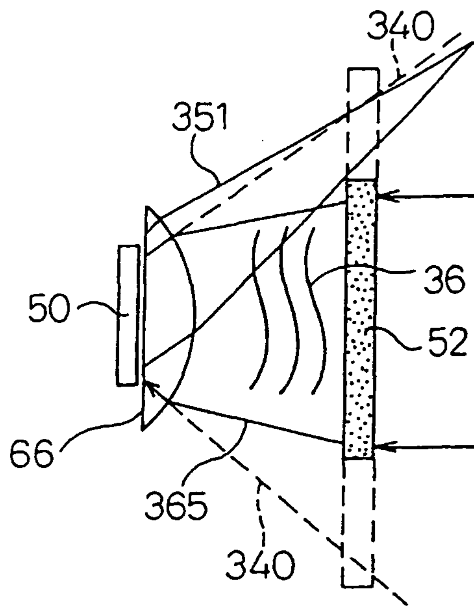
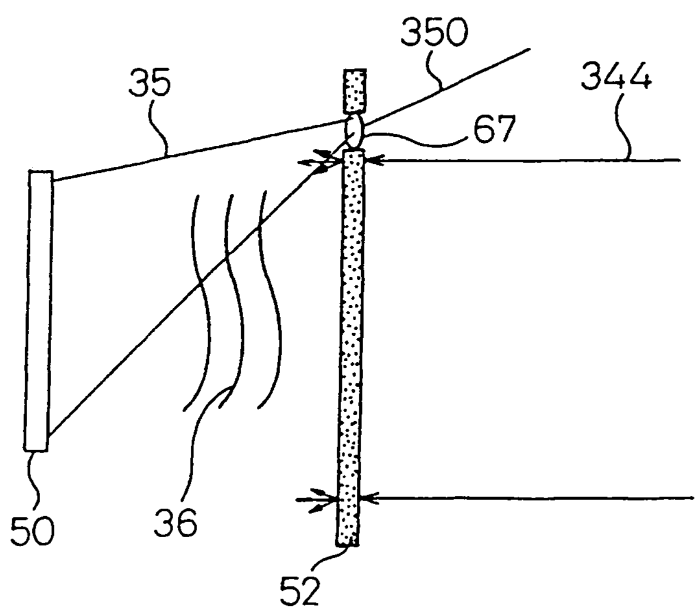


Fig.42



(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 828 202 A3

(12) EUROPEAN PATENT APPLICATION

(88) Date of publication A3:
02.09.1998 Bulletin 1998/36

(43) Date of publication A2:
11.03.1998 Bulletin 1998/11

(21) Application number: 97115344.0

(22) Date of filing: 04.09.1997

(51) Int. Cl.[6]: **G03H 1/04**, G02B 5/32

(84) Designated Contracting States:
AT BE CH DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE

(30) Priority: 05.09.1996 JP 257588/96
02.09.1997 JP 254346/97

(71) Applicant: DENSO CORPORATION
Kariya-City Aichi-Pref. 448 (JP)

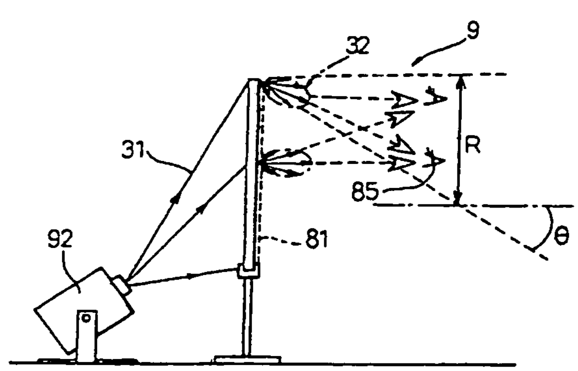
(72) Inventors:
- Takada, Kenichiro
  Kariya-city, Aichi-pref. 448 (JP)
- Nishii, Katuyoshi
  Kariya-city, Aichi-pref. 448 (JP)
- Koike, Satoshi
  Kariya-city, Aichi-pref. 448 (JP)
- Kurokawa, Kazumasa
  Kariya-city, Aichi-pref. 448 (JP)
- Shiozawa, Masahiro,
  c/o Nippon Soken, Inc.
  Nishio-shi, Aichi (JP)
- Kanda, Tomoyuki
  Kariya-City, Aichi-pref. 448 (JP)

(74) Representative:
Klingseisen, Franz, Dipl.-Ing. et al
Patentanwälte,
Dr. F. Zumstein,
Dipl.-Ing. F. Klingseisen,
Postfach 10 15 61
80089 München (DE)

(54) Method for producing transparent type hologram

(57) Method for producing a of a transparent type hologram screen of an wide visible range. A photosensitive member 50 and a light source of a reference light are arranged on the same side of the light diffusing body. A light source of an object light is arranged on the opposite side of the light diffusing body 52, so that the light is transmitted through the light diffusing body 52, thereby generating a object light 36. A light from a light source of a reference light is reflected at the light diffusing body 52 or a member such as a half mirror or a transparent, reflective hologram element arranged at a front side of the light diffusing body.

Fig.1



EP 0 828 202 A3

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 97 11 5344

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	FR 2 640 772 A (LUNAZZI JOSE) 22 June 1990 * page 3, line 23 - line 34 * * page 4, line 32 - line 36 * * figures * ---	1	G03H1/04 G02B5/32
X	EP 0 349 884 A (HUGHES AIRCRAFT CO) 10 January 1990 * column 6, line 3 - line 24 * * figure 10 * ---	1	
X	DE 27 32 843 A (YEDA RES & DEV) 2 February 1978 * page 15, paragraph 2 * * figure 2A * -----	1	

TECHNICAL FIELDS SEARCHED (Int.Cl.6)
G03H
G02B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	14 July 1998	Krametz, E

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